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REPORT OF THE NATIONAL CONSERVATION COMMISSION

WITH ACCOMPANYING PAPERS

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SPECIAL MESSAGE FROM THE
PRESIDENT OF THE UNITED STATES
TRANSMITTING A REPORT OF THE
NATIONAL CONSERVATION COMMISSION, WITH ACCOMPANYING PAPERS

IN THREE VOLUMES

VOLUME III

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CONTENTS.

ILLUSTRATIONS.

ACCOMPANYING PAPERS

LANDS, MINERALS, AND NATIONAL VITALITY

CROP YIELD PER ACRE.

By V. H. Olmsted,

Chief of Bureau of Statistics, United States Department of Agriculture.

In compliance with the request of the commission for information regarding the average yield per acre, by decades, of certain leading representative agricultural crops of the United States, to be used in answering one of the inquiries propounded by the executive committee of the National Conservation Commission, I hand you herewith three statements, marked "A," "B," and "C," respectively.

The statement marked "A" shows the average yield per acre for the decades 1867–1876, 1877–1886, 1887–1896, and 1897–1906, of nine of the principal crops, to wit, corn, wheat, oats, barley, rye, hay, buckwheat, potatoes, and cotton, for each State and Territory, with the total average yield for the same decades for the United States of each crop.

The statement marked "B" shows the average yield per acre in the forty years 1867–1906, and the average yield in each decade for the same crops covered by the statement marked "A," in the United States as a whole.

The statement marked "C" compares, in percentages, the average yield per acre of the crops in question in each decade with the average yield per acre for the entire forty years, the yield for the whole period being represented by 100.

The inquiry to which these figures are given in reply, taken in connection with its subinquiries, is apparently based on the presumption that there has been, and is constantly going on, a diminution in the average productivity of the soil.

A perusal of the figures submitted shows such presumption to be erroneous. A brief glance at the statement marked "C" will convince one of this fact, as it stands out with great plainness that during the decade ending with 1906 there was a substantial increase in productivity as compared with the entire forty-year period. This is not true of a single crop only, but of every crop covered by the statement, and were it possible to give exhaustive figures regarding many other crops the same results would undoubtedly be shown.

That there should be an increase instead of a decrease in the soil productivity might be expected when the work which has been carried on by the Department of Agriculture is taken into consideration, particularly during the last dozen years. It would be strange, indeed, if all the work of this great department should result in no advantage to the agricultural interests of the country.

A brief mention of some of the lines along which the betterment of agricultural industry has been accomplished by the Department of Agriculture may not be out of place in this connection:

The Bureau of Plant Industry, whose ramifications extend to every section of the country, is constantly teaching the farmers how to improve their crops by breeding and selection; how to put into operation the best methods of farm practice; and how to prevent diseases in plants. It is constantly securing and distributing new and improved varieties of seeds and plants; studies and disseminates information as to their adaptability to the various sections of the United States, and is continuously carrying on the enormous work which must, in the very nature of things, result in vast improvement in agricultural conditions.

The Bureau of Soils investigates soils in their relation to crops; their adaptation to crops; their proper utilization and management; and information is disseminated in relation thereto, to which all farmers have access.

The Office of Experiment Stations represents the department in its relations to the agricultural colleges and experiment stations scattered throughout the length and breadth of the United States. In these experiment stations ocular demonstrations are given of the best methods of cultivation and of the best varieties for the cultivator.

The Bureau of Entomology obtains and disseminates information in regard to injurious insects affecting field crops, fruits, truck crops, forest, and forest products, etc., and gives instructions as to the best methods for their suppression or the prevention of their ravages.

The Bureau of Biological Survey investigates the economic relations of birds and mammals which are beneficial to agriculture, and also of those which are destructive.

The Bureau of Chemistry makes such investigations and analyses as pertain in general to the interests of agriculture, dealing with fertilizers and agricultural products.

The Weather Bureau gives timely warning by the display of weather and flood signals, and issues storm warnings for the benefit of agriculture, which information enables farmers to adopt measures for the protection of their growing crops or those already harvested.

The beneficial effects of the work of these bureaus, and of the Department of Agriculture generally, are clearly shown by the figures covering the last decade, during which their operations have been actively and widely extended.

The agricultural resources of the country have been, and are constantly being, conserved by the Department of Agriculture; and it is impossible to estimate in terms of dollars and cents the enormous benefit that has accrued to the farmers of the United States through the operations of this department. The amount of money which has been expended by it under congressional appropriations is a mere bagatelle when compared with the amount gained by the people through its operations.

A.

Yield per acre.

(Ten-year average.)

States and Territories.	Corn (bushels).				Wheat (bushels).				Oats (bushels).			
	1867–1876.	1877–1886.	1887–1896.	1897–1906.	1867–1876.	1877–1886.	1887–1896.	1897–1906.	1867–1876.	1877–1886.	1887–1896.	1897–1906.
Maine	29.1	33.8	34.9	35.1	13.2	13.9	16.6	22.4	25.6	27.5	33.1	36.4
New Hampshire	36.5	34.8	35.2	33.6	15.1	14.6	16.4	[d]17.1	32.9	34.9	32.6	33.2
Vermont	36.6	34.7	36.3	34.5	16.4	17.2	19.3	21.0	34.6	34.6	34.2	36.9
Massachusetts	34.7	32.3	36.7	35.6	17.0	17.8	[a]14.8	......	30.6	31.0	31.5	32.9
Rhode Island	27.7	30.4	31.5	31.8	[e]16.8	[b]12.8	......	......	30.6	28.7	28.5	29.4
Connecticut	30.9	29.2	33.8	36.0	16.9	16.7	[e]16.1	[d]19.8	30.4	28.5	26.7	31.3
New York	31.9	30.5	31.3	30.4	14.1	15.6	15.4	17.9	31.8	30.5	26.7	31.4
New Jersey	35.8	31.9	31.5	34.6	14.6	13.5	13.4	16.4	27.5	29.1	26.7	26.3
Pennsylvania	35.2	31.9	31.6	34.5	13.5	13.4	13.7	16.2	30.2	30.2	26.0	29.5
Delaware	21.9	21.2	20.4	27.6	11.7	12.1	12.7	15.8	17.7	22.3	20.5	23.2
Maryland	24.6	25.2	24.6	32.3	10.9	12.8	13.8	15.8	19.4	20.7	20.2	23.9
Virginia	20.0	17.5	18.0	21.3	8.5	8.3	8.9	10.6	15.9	11.9	14.0	16.0
West Virginia	29.2	25.3	22.9	26.4	10.4	10.7	10.2	11.0	23.5	19.8	19.7	22.4
North Carolina	14.6	12.9	12.6	13.7	7.3	6.4	6.4	7.7	13.8	11.0	11.3	13.9
South Carolina	10.0	8.9	10.2	9.8	6.4	6.3	5.9	7.9	11.1	11.4	11.3	15.5
Georgia	11.8	10.3	11.2	10.6	7.1	6.8	6.5	8.1	12.1	10.9	11.9	14.0
Florida	10.6	9.6	10.1	9.4	[c]9.0	[b]4.8	......	......	13.0	11.1	11.4	12.4
Ohio	35.2	32.1	29.7	34.9	12.8	14.9	13.8	14.9	29.0	31.2	29.1	35.0
Indiana	31.7	30.1	29.2	34.5	11.5	14.3	13.3	13.4	24.5	27.5	26.2	30.9
Illinois	29.3	27.2	30.6	34.0	11.5	13.5	14.4	13.5	29.1	34.4	30.0	32.6
Michigan	31.9	31.8	27.6	32.0	13.2	16.5	14.5	13.8	31.8	32.9	28.9	32.8
Wisconsin	32.0	29.5	28.6	33.6	13.2	12.4	13.2	16.0	33.6	32.9	31.0	35.1
Minnesota	31.5	31.4	27.7	29.4	14.4	13.4	13.7	13.0	34.1	35.2	30.9	33.2
Iowa	34.2	31.4	31.5	32.5	11.6	10.8	13.3	14.1	34.6	33.9	30.8	31.6
Missouri	29.8	28.1	28.2	28.0	12.3	11.5	12.7	12.5	28.4	26.9	23.5	23.0
North Dakota	.....	[e]25.2	[f]22.6	21.9	.....	[e]14.1	[f]14.0	12.3	.....	[e]33.7	[f]27.0	30.1
South Dakota			[f]18.3	26.6			[f]11.0	11.4			[f]23.4	31.3
Nebraska	32.5	35.2	26.2	27.7	13.4	11.8	11.1	16.2	32.7	30.9	23.2	29.0
Kansas	34.5	31.2	22.8	22.1	15.0	13.6	12.7	14.2	32.1	30.1	23.1	24.9
Kentucky	29.4	25.2	25.2	26.0	9.5	9.8	10.9	11.8	21.4	19.6	18.9	21.2
Tennessee	23.2	21.0	21.7	22.4	8.0	6.4	8.4	9.9	17.3	15.4	15.2	17.5
Alabama	14.4	12.3	12.8	13.0	7.7	6.4	7.0	9.4	13.3	12.1	12.3	14.4
Mississippi	16.1	14.0	14.8	15.2	9.5	5.8	7.4	9.6	15.6	12.3	12.6	15.8
Louisiana	18.3	16.2	16.0	16.8	[d]9.1	[b]3.4	......	......	[i]16.5	[i]13.3	13.5	16.8
Texas	23.6	18.9	18.3	19.0	12.9	10.5	10.5	12.2	27.1	26.7	23.1	29.1
Indian Territory	......	......	......	[f]27.2	......	......	......	[f]12.1	......	......	......	[f]31.7
Oklahoma	......	......	......	[h]23.5	......	......	[e]11.9	14.2	......	......	......	[f]30.6
Arkansas	25.7	21.0	18.5	18.8	10.5	7.0	8.6	9.4	22.5	18.7	17.7	19.5
Montana	......	[e]26.2	[f]26.4	22.0	......	[e]17.5	20.8	26.7	......	[e]35.7	33.2	41.2
Wyoming	......	......	[e]23.9	24.9	......	[e]17.4	[f]21.0	23.0	......	[e]30.0	[g]30.5	34.6
Colorado	......	[g]26.2	21.3	19.9	......	[g]19.2	19.0	24.6	......	[g]31.1	28.0	33.4
New Mexico	......	[e]20.4	20.3	24.5	......	[e]13.2	15.6	20.0	......	[e]21.8	26.7	28.5
Arizona	......	[e]21.3	[e]19.8	[f]23.5	......	[e]13.8	16.2	21.8	......	[a]25.0	......	[f]33.0
Utah	......	[e]22.7	20.4	24.5	......	[e]17.5	18.8	23.5	......	[e]26.0	29.5	37.1
Nevada	[g]30.9	[g]23.9	[a]27.8	......	[g]21.1	[g]17.3	19.2	26.0	[g]33.9	[g]31.1	[b]25.2	[f]36.6
Idaho	......	[e]22.3	[e]24.8	[f]27.8	......	[e]16.9	19.2	23.8	......	[e]33.0	32.5	39.2
Washington	......	[e]26.3	[g]19.0	21.1	......	[e]16.5	17.7	23.3	......	[e]37.7	35.8	44.1
Oregon	[h]29.5	26.0	23.8	24.3	[h]18.6	17.1	17.1	18.7	[h]35.4	30.4	27.1	28.2
California	[i]37.9	28.6	30.6	29.7	[i]14.6	12.9	12.7	11.6	[i]33.9	27.3	28.3	29.6
The Territories	[i]29.4	[e]29.4	......	......	[i]21.5	[e]15.4	......	......	[i]34.1	[e]29.1	......	......
United States	26.2	25.1	24.0	25.4	12.0	12.5	12.7	13.8	27.5	27.8	25.5	30.1

[a] 1 year. [b] 2 years. [c] 3 years. [d] 4 years. [e] 5 years. [f] 6 years. [g] 7 years. [h] 8 years. [i] 9 years.

Yield per acre—Continued.

States and Territories.	Barley (bushels).				Rye (bushels).				Hay (tons).			
	1867–1876	1877–1886	1887–1896	1897–1906	1867–1876	1877–1886	1887–1896	1897–1906	1867–1876.	1877–1886.	1887–1896.	1897–1906.
Maine	19.3	21.6	25.0	28.8	16.3	14.0	14.0	[d]15.9	0.88	0.97	0.97	1.06
New Hampshire	24.7	21.6	24.1	21.9	17.2	11.7	14.2	[d]16.9	1.00	.95	.98	1.08
Vermont	24.1	25.7	26.7	31.2	16.5	15.4	14.3	17.3	1.05	1.05	1.17	1.27
Massachusetts	23.0	23.0	23.7	[d]28.7	16.2	15.0	15.4	16.1	1.10	1.14	1.15	1.30
Rhode Island	23.2	[i]22.6	24.7	[d]28.2	16.0	12.6	[f]13.2	......	1.02	1.04	.96	1.05
Connecticut	22.8	[i]21.8	[f]22.2	......	14.3	14.2	14.0	17.7	1.19	1.08	1.02	1.12
New York	21.9	23.0	21.1	24.4	13.8	13.0	13.8	16.3	1.21	1.15	1.09	1.24
New Jersey	[h]23.5	[e]17.0	[d]21.2	......	13.7	11.6	12.6	16.1	1.26	1.14	1.18	1.29
Pennsylvania	21.4	21.9	19.6	21.6	13.7	11.7	13.1	16.3	1.19	1.20	1.15	1.30
Delaware	[h]19.8	......	[d]21.9	......	9.3	10.3	[f]8.2	[f]13.4	1.13	1.02	1.14	1.30
Maryland	[h]20.4	[e]25.8	[d]22.6	[f]25.8	12.1	11.3	11.2	14.8	1.11	1.09	1.13	1.22
Virginia	[h]16.3	[f]16.2	[f]18.4	[f]24.8	10.2	7.7	8.4	11.6	1.18	1.16	1.07	1.22
West Virginia	17.0	[i]16.5	[f]22.0	......	13.0	9.9	9.4	11.1	1.17	1.10	1.04	1.36
North Carolina	[h]16.0	[f]11.1	[e]18.5	......	9.0	6.6	6.7	9.0	1.29	1.25	1.29	1.54
South Carolina	[h]12.9	[e]14.2	[d]19.3	......	6.4	4.8	5.6	7.5	1.01	1.15	1.24	1.37
Georgia	[i]14.0	[g]14.2	[e]18.3	......	[i]7.4	[g]5.6	6.0	7.4	1.29	1.34	1.28	1.53
Florida	[c]14.2	......	[d]21.2	......	[d]9.6	[c]4.9	[d]13.6	......	[c]1.15	[e]1.06	[g]1.39	1.38
Ohio	22.8	23.4	24.0	27.6	12.8	13.2	14.0	17.1	1.19	1.24	1.17	1.35
Indiana	21.5	[i]23.3	20.8	25.5	14.0	12.4	13.8	14.5	1.29	1.32	1.17	1.36
Illinois	22.4	21.7	22.3	27.5	16.1	16.1	14.9	16.8	1.36	1.38	1.18	1.32
Michigan	21.6	24.3	21.5	24.8	15.4	12.9	13.1	15.0	1.22	1.27	1.15	1.34
Wisconsin	26.0	24.5	25.7	29.2	15.6	14.4	14.3	16.3	1.35	1.28	1.19	1.54
Minnesota	25.2	26.0	24.9	26.4	18.5	16.4	16.3	19.0	1.46	1.40	1.30	1.66
Iowa	25.0	22.5	23.0	25.8	17.9	[i]13.4	15.7	17.7	1.48	1.35	1.25	1.54
Missouri	22.0	[g]20.5	20.2	20.5	15.8	13.1	12.7	14.3	1.40	1.25	1.18	1.27
North Dakota } South Dakota	......	[e]22.8	[h]21.2	24.4	......	[e]16.2	[h]13.7	15.6	......	[e]1.32	[h]1.23	1.46
South Dakota			[h]18.6	25.0			[h]10.2	16.6			[h]1.09	1.36
Nebraska	26.5	20.1	19.5	24.9	18.6	[i]15.0	12.4	17.0	1.55	1.45	1.15	1.58
Kansas	24.0	19.0	16.9	21.5	18.8	16.5	10.6	14.3	1.46	1.40	1.16	1.43
Kentucky	20.4	22.7	23.0	22.3	11.2	10.2	10.9	13.2	1.25	1.24	1.19	1.36
Tennessee	19.0	[g]14.0	16.0	18.2	9.6	[i]7.2	7.6	11.3	1.31	1.26	1.23	1.50
Alabama	[e]12.6	[e]10.4	[d]20.2	......	[i]8.9	[g]5.7	7.9	10.0	1.25	1.31	1.48	1.74
Mississippi	[d]11.2	......	[d]20.4	......	[i]9.9	[e]6.9	[f]7.3	......	1.32	1.32	1.47	1.68
Louisiana	[a]18.2	......	[d]21.3	......	[e]11.2	[e]7.4	[e]9.9	......	[i]1.45	[f]1.15	1.57	1.99
Texas	25.7	[g]18.1	15.2	22.6	15.9	[i]11.8	8.9	12.7	1.40	1.26	1.22	1.61
Indian Territory	......	......	......	......	......	......	......	......	......	......	......	[f]1.41
Oklahoma	......	......	......	[f]28.5	......	......	......	[f]14.0	......	......	[a]1.32	[f]1.32
Arkansas	[d]15.0	......	[d]20.0	......	13.1	8.6	8.3	11.1	1.38	1.31	1.22	1.53
Montana	......	[e]28.5	27.5	36.0	......	......	......	[f]22.8	......	[e]1.09	1.16	1.69
Wyoming	......	......	......	[f]28.6	......	......	......	[f]20.2	......	[e]1.18	1.22	1.93
Colorado	......	[g]23.4	26.1	31.6	......	[g]18.5	16.2	17.2	......	[g]1.15	1.75	2.23
New Mexico	......	[e]19.5	22.0	27.0	......	......	......	......	......	[e]1.10	1.70	2.59
Arizona	......	[e]19.2	[i]22.6	[f]34.4	......	......	......	......	......	[e].98	1.70	3.00
Utah	......	[e]22.4	26.9	36.1	......	[e]11.0	14.5	16.7	......	[e]1.30	1.81	3.02
Nevada	[g]27.2	[g]21.8	[i]27.5	[f]34.8	[a]25.0	......	[d]12.0	......	[g]1.40	[g]1.32	2.05	2.50
Idaho	......	[e]27.1	25.8	37.7	......	[e]13.1	[d]12.2	[f]20.6	......	[e]1.21	1.75	2.85
Washington	......	[e]30.3	29.9	39.0	......	[e]16.1	15.4	18.3	......	[e]1.31	1.57	2.24
Oregon	[h]29.0	26.8	25.2	30.9	[h]24.2	17.8	12.4	14.6	[h]1.46	1.54	1.59	2.08
California	[i]23.2	20.6	21.2	22.5	[i]21.5	[i]12.0	12.8	12.0	[i]1.41	1.47	1.54	1.83
The Territories	[i]28.8	[b]20.6	[d]24.2	......	[d]24.2	[b]17.4	[d]12.8	......	[h]1.46	[e]1.41	......	......
United States	22.8	22.4	22.7	25.5	13.6	13.0	12.9	15.7	1.22	1.24	1.20	1.43

[a] 1 year. [b] 2 years. [c] 3 years. [d] 4 years. [e] 5 years. [f] 6 years. [g] 7 years. [h] 8 years. [i] 9 years.

Yield per acre—Continued.

States and Territories.	Buckwheat (bushels).				Potatoes (bushels).				Cotton (pounds).			
	1867–1876.	1877–1886.	1887–1896.	1897–1906.	1867–1876.	1877–1886.	1887–1896.	1897–1906.	1867–1876.	1877–1886.	1887–1896.	1897–1906.
Maine	22.2	21.1	25.8	29.6	113	99	110	153	....	....	....	....
New Hampshire	19.5	19.1	20.8	22.0	120	96	98	106	....	....	....	....
Vermont	20.3	20.7	22.9	23.4	140	107	101	109	....	....	....	....
Massachusetts	14.0	14.0	16.4	17.9	112	95	99	98	....	....	....	....
Rhode Island	[e]15.5	[f]10.4	[d]13.1	....	92	91	103	123	....	....	....	....
Connecticut	17.1	12.7	13.9	17.4	95	79	86	94	....	....	....	....
New York	18.8	14.9	16.2	17.7	96	81	77	80	....	....	....	....
New Jersey	16.5	14.4	14.2	19.3	78	82	78	91	....	....	....	....
Pennsylvania	18.2	14.5	15.1	18.4	89	77	77	79	....	....	....	....
Delaware	[h]18.5	[f]13.4	[h]15.4	16.1	77	71	63	70	....	....	....	....
Maryland	17.0	14.6	14.0	16.5	70	71	70	75	....	....	....	....
Virginia	14.8	12.7	11.3	16.3	67	67	70	72	175	177	155	177
West Virginia	16.8	12.9	14.0	19.0	77	71	70	78	....	....	....	....
North Carolina	[h]17.4	[g]10.0	11.7	14.6	86	71	71	68	164	172	170	207
South Carolina	....	....	....	....	78	65	66	74	154	152	157	189
Georgia	....	....	....	....	[i]83	[i]62	64	63	154	146	151	175
Florida	....	....	....	....	[e]95	[f]68	74	76	128	108	111	121
Ohio	13.8	12.4	13.4	17.0	84	75	66	77	....	....	....	....
Indiana	15.8	[i]12.2	13.0	15.9	75	70	64	73	....	....	....	....
Illinois	14.6	11.9	12.4	15.2	75	78	66	80	....	....	....	....
Michigan	16.5	14.5	13.8	14.3	92	87	72	83	....	....	....	....
Wisconsin	16.5	11.8	12.6	15.4	88	83	77	94	....	....	....	....
Minnesota	16.7	12.5	12.2	15.1	104	99	85	87	....	....	....	....
Iowa	18.1	[i]12.3	12.8	14.8	97	85	73	81	....	....	....	....
Missouri	18.5	[i]13.3	12.1	14.2	80	76	74	76	231	205	210	242
North Dakota	....	[d]8.1	[g]12.1	[d]11.9	....	[e]89	[h]83	94	....	....	....	....
South Dakota			[i]11.9	....			[h]62	82	....	....	....	....
Nebraska	[f]18.9	[i]12.6	10.7	14.8	90	83	63	83	....	....	....	....
Kansas	17.1	12.7	[i]10.5	[f]13.4	98	71	60	75	....	....	....	....
Kentucky	[h]16.1	[f]9.5	[d]12.4	....	70	67	65	67	....	....	....	....
Tennessee	12.4	[i]10.9	11.3	15.6	72	71	64	60	165	190	165	184
Alabama	....	....	....	....	67	72	65	65	152	142	150	166
Mississippi	....	....	....	....	78	69	67	75	185	176	178	208
Louisiana	....	....	....	....	84	[f]63	66	64	212	209	207	244
Texas	....	....	....	....	100	66	66	66	233	190	189	181
Indian Territory	....	....	....	....	....	....	....	[f]73	....	....	....	249
Oklahoma	....	....	....	....	....	....	....	[f]80	....	....	....	240
Arkansas	....	....	....	....	80	80	70	67	217	226	203	215
Montana	....	13.2	[d]13.4	....	....	[e]104	108	144	....	....	....	....
Wyoming	....	....	....	....	....	[e]95	109	133	....	....	....	....
Colorado	....	....	....	....	....	[g]79	92	112	....	....	....	....
New Mexico	....	....	....	....	....	[e]79	72	68	....	....	....	....
Arizona	....	....	....	....	....	[e]64	[i]71	....	....	....	....	....
Utah	....	....	....	....	....	[e]94	103	140	....	....	....	....
Nevada	27.5	....	....	....	[g]104	[g]94	118	144	....	....	....	....
Idaho	....	....	....	....	....	[e]99	116	139	....	....	....	....
Washington	....	22.0	[d]15.0	....	....	[e]119	121	132	....	....	....	....
Oregon	[f]22.3	[f]14.5	[i]17.5	[d]15.5	[h]115	109	92	107	....	....	....	....
California	[h]23.2	[e]20.4	[h]18.8	....	[i]117	97	82	119	....	....	....	....
The Territories	[a]28.8	....	[d]14.0	....	[i]120	[e]111	....	....	....	....	....	....
United States	17.6	14.5	15.3	18.1	90	82	75	86	181	170	172	191

[a] 1 year. [b] 2 years. [c] 3 years. [d] 4 years. [e] 5 years. [f] 6 years. [g] 7 years. [h] 8 years. [i] 9 years.

B.

The average yield per acre in the forty years 1867–1906 and the average yield in each decade, for specified crops in the United States, were as follows:

Crop.	1867–1906.	1867–1876.	1877–1886.	1887–1896.	1897–1906.
Corn......bushels..	25.2	+26.2	25.1	−24	25.4
Wheat......do....	12.7	−12	12.5	12.7	+13.8
Oats......do....	27.7	27.5	27.8	−25.5	+30.1
Barley......do....	23.4	22.8	−22.4	22.7	+25.5
Rye......do....	13.8	13.6	13.8	−12.9	+15.7
Hay......tons..	1.28	1.22	1.24	−1.20	+1.43
Buckwheat......bushels..	16.4	17.6	−14.5	15.3	+18.1
Potatoes......do....	83.3	+90	82	−75	86
Cotton......pounds..	179	181	−170	172	+191

C.

Representing the average yield of the forty years 1867–1906, by 100, the relative average yield per acre in each decade was as follows:

Crop.	1867–1876.	1877–1886.	1887–1896.	1897–1906.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Corn	104	100	95	101
Wheat	94	98	100	108
Oats	99	100	92	109
Barley	98	96	97	109
Rye	99	94	93	114
Hay	96	97	95	112
Buckwheat	107	89	93	111
Potatoes	108	99	90	103
Cotton	102	95	96	107

CROP YIELD AND SOIL COMPOSITION.

By Dr. Milton Whitney,
Chief of Bureau of Soils, United States Department of Agriculture.

THE FERTILITY OF THE SOILS OF THE UNITED STATES AS MEASURED BY THE YIELDS OF CROPS.

At the recent conference at the White House on the conservation of our natural resources, Mr. J. J. Hill gave very forcible expression to an idea which is quite commonly held, that the fertility of our soils is being reduced and that they are becoming exhausted. He used three illustrations to prove the point, namely, the yield per acre of wheat in the States of New York, Kansas, and Minnesota. In New York the average yield for the past ten years, he states, is about 18 bushels; during the first five years of this period the yield was 18.4 and during the last five years 17.4 bushels, apparently showing an alarming decrease during a comparatively short time. If, however, he had gone further back into the official records of the Bureau of Statistics of the Department of Agriculture, he would have found that the average yield of the State of New York for the past forty years (1866–1907) is 15.7 bushels, the average yield for each decade since 1866 being 14.1, 15.6, 15.4, and 17.9, indicating an apparent increase instead of a decrease with the average acreage for each decade of 592,584, 743,209, 547,191, and 452,204.

In like manner he called attention to the fact that the average yield for the past ten years in Kansas was 14.16 bushels. For the first half of the period the yield was 15.14 bushels and for the last half 13.18, but the department records show that the average yield for Kansas for the past forty years is 13.9 bushels, so that on the face of it his argument again falls down, but in this case there is another factor which did not enter markedly in the case of New York, namely, that the acreage upon which the estimates of the yield per acre is made has materially changed. The average yield of the four decades is 15.0, 13.6, 12.7, and 14.2, and the acreage for the corresponding decades 372,788, 1,617,317, 2,523,637, and 4,818,335. The development of agriculture in Kansas, as expressed in the increase of nearly 1,200 per cent in wheat acreage, has been in the direction of the semiarid portion of the State and on lands which were formerly not considered suitable for cultivated crops, so the indications are certainly strong that the fertility of the Kansas soils, as expressed by the average yield of wheat, has not declined in the past forty years.

In the case of Minnesota he states that the average yield for the past ten years was 12.96 bushels. For the first half of this period the yield was 13.12 and for the last half 12.8. But the average yield of wheat in Minnesota for the past forty years was only 13.6 bushels. The yield for each decade was 14.4, 13.4, 13.7, and 13.0, with an acreage of 1,309,367, 2,705,898, 3,130,794, and 5,281,253, giving another case where the area upon which the average yield is estimated has been considerably increased.

YIELD PER ACRE OF WHEAT IN THE UNITED STATES.

A careful study of the official records of the Bureau of Statistics of the Department of Agriculture fails entirely to bear out the general impression that the yields are declining in the United States as a whole or in any considerable portion of the area, but on the contrary indicates strongly that the yields as a whole are increasing, although to a slight extent. It is, of course, extremely difficult to draw conclusions from estimates, even with records extending over a period of forty years, in a country which has been rapidly developing and when the basis of the estimates, namely the area, is rapidly increasing and where the seasonal variations are large.

The average yield of wheat in the United States for the past forty years is 12.7 bushels. The four decades show 12.0, 12.5, 12.7, and 13.8, indicating an apparent regular increase in productivity, but at the same time the acreage has increased 21,661,078, 35,060,189, 32,623,809, and 45,540,593, so that it is not safe to draw this inference from the figures above. There are 33 States which have a higher average yield per acre than the United States as a whole and 15 having a lower yield. If proportionately more of the increase in acreage has occurred in the 33 States having above the average yield for the country as a whole, the increase in yield per acre for the United States would be accounted for. This line has not been followed out as it is obvious that we must look further into the facts before any safe conclusions can be drawn as to any change in the fertility of our soils.

AVERAGE YIELD PER ACRE OF WHEAT IN THE SEVERAL STATES.

In the following table the States for which the Bureau of Statistics has full forty-year records (except California, which has records extending over only thirty-nine years) are arranged in the order of the average yield per acre of wheat over this period.

Average yield of wheat, in bushels per acre, for forty years, 1866–1907.

State.	Yield.	State.	Yield.	State.	Yield.
Vermont	18.5	Maryland	13.3	West Virginia	10.6
Maine	16.5	Illinois	13.2	Kentucky	10.5
New York	15.7	Nebraska	13.1	Virginia	9.1
New Jersey	14.5	Indiana	13.1	Arkansas	8.9
Michigan	14.5	Delaware	13.1	Tennessee	8.2
Pennsylvania	14.2	California	12.9	Mississippi	8.1
Ohio	14.1	United States	12.7	Alabama	7.6
Kansas	13.9	Iowa	12.4	Georgia	7.1
Wisconsin	13.7	Missouri	12.2	North Carolina	6.9
Minnesota	13.6	Texas	11.5	South Carolina	6.6

The most obvious fact brought out by this table is that the arrangement shows roughly three geographical groups of States, the Southern States having very small yields, the New England States with New York showing the largest yields (from two to three times as large as the Southern States), and the great wheat States of the Middle West coming in between.

This great difference between the States will be considered later; what concerns us now is the variation in the yield per acre for any particular State or group of States. The average yield for each of the four decades is given in the table prepared by the Bureau of Statistics for each of the States. These yields show a general tendency to increase, but there are fluctuations which make it difficult to draw satisfactory conclusions as the seasonal variations have not been entirely eliminated even over so long a period, and we know that great changes have occurred in the acreage of certain of the States; it is important to see the effect, if any, upon the average yield.

In considering the question of change in the fertility of the land as measured by the yield per acre of crops, it is necessary to have records covering a sufficiently long period to reduce the seasonal variations to a very small amount, and it is unfortunate that we have not available continuous records in this country for more than forty years, either for a State or for any individual farm or constant area of any soil type.

NEW ENGLAND STATES AND NEW YORK.

The nearest approach to this constant acreage and uniformity of yield in several States, where at the same time records of the Bureau of Statistics are available for forty consecutive years, is in what may be taken as two groups of States, namely, Maine, Vermont, and New York; and New Jersey, Pennsylvania, Delaware, and Maryland. In all of these States agriculture is old and in the past forty years there has been relatively very little new land to take up.

In Maine and Vermont the acreage in wheat, at all times small, has been reduced considerably in later years, and the yield per acre has materially increased during the successive decades. It may be argued that this increase in yield per acre is due to the abandonment of the lands less well adapted to wheat, but in New York, with a very much larger acreage but with a much smaller difference in acreage, the yield has increased nearly as much. If we take the figures representing the yield per acre for each of the States for the four decades as an indication only of fertility and regardless of acreage and add them together, we get a factor of relative productivity for the different decades in which the seasonal fluctuations will be more nearly eliminated than if we had used the weighted averages, and while the results show the same order of increase we get a smoother curve.

Reducing these sums to figures approximately equal to the average yields per acre of the several States, by dividing by the number of States, the relative yields of the several decades are represented by the figures 14.6, 15.6, 17.4, and 20.5, indicating a decided and progressive increase in the productivity of the lands.

These States, however, show a remarkable falling off in the total land values and contain many so-called "abandoned" farms, but so far as the production of wheat is concerned this is not due to a decline in fertility or the wearing out of the soil, and the explanation must be sought in changed economic conditions connected with the relative cost of production and other conditions which are outside of the scope of this article.

NEW JERSEY, PENNSYLVANIA, DELAWARE, AND MARYLAND.

The effect of the intelligent reduction of acreage mentioned as a possible factor in increasing the yield per acre of wheat in the New England States and New York can not hold with equal weight with the second group of States above mentioned, as the acreage has varied but little in the States of New Jersey, Pennsylvania, Delaware, and Maryland. Nevertheless by combining the yields per acre as fertility factors for these States, as was done in the last group, the relative order of productivity for the different decades is represented by the figures 12.7, 12.9, 13.4, and 16.0, again showing a regular increase for a group of some of the older States, where the land has practically all been settled for much longer than the forty years.

VIRGINIA, NORTH CAROLINA, SOUTH CAROLINA, GEORGIA, AND ALABAMA.

In these States the average yields per acre have been closely comparable and the acreage not very different either among the States or during the period of forty years. In each case there is an indication of a slight increase of productivity, although both the first and last decades show larger yields than either of the intermediate ones. The relative order of the group of States for the four decades is represented by the figures 7.4, 6.8, 6.9, and 8.7.

OHIO, INDIANA, AND ILLINOIS.

Ohio, Indiana, and Illinois form another group of States having nearly the same acreage and the same yields per acre in which the yield per acre for the past forty years has apparently at least held its own or even increased, the relative productivity of the three States for the four decades being represented by the figures 11.9, 14.2, 13.5, and 13.9.

WISCONSIN, MICHIGAN, IOWA, AND ILLINOIS.

We come now to two groups of States showing some marked differences in acreage in the last forty years. The sum of the average acreage in wheat for the four decades in the first of these groups (Wisconsin, Michigan, Iowa, and Illinois) is 7,336,041, 8,525,988, 5,697,582, and 4,572,012. The relative yield per acre of the group of States for the corresponding decades may be expressed by the figures 12.4, 13.3, 13.8, and 14.3.

It may be argued, as in the case of the New England States, that in restricting the acreage the lands less well adapted to wheat have been first abandoned and the average yield increased in this way.

MINNESOTA, NEBRASKA, KANSAS, AND MISSOURI.

We have another group of closely adjacent States, namely, Minnesota, Nebraska, Kansas, and Missouri, where the sum of the mean acreage for the several decades has been 2,693,576, 7,799,182, 8,654,331, and 14,364,930, while the relative yield per acre of the group may be expressed by the figures 13.8, 12.6, 12.6, and 14, again an apparent increase. The figures for Minnesota and Kansas, it is true, appear to show a slight decrease, but the seasonal variations in both these States are large, so large they are not eliminated in the ten-year periods. For example, in Nebraska in the first and third decades the difference between the highest and lowest yield is actually greater than the average yield for forty years. The larger the groups of States that can be compared, therefore, the better. The relative yield per acre for the eight States in this and the preceding group for the several decades may be expressed by the figures 13.1, 12.9, 13.2, and 14.1. From the data available it is reasonable to assume that the yield per acre in each of these states has increased to some extent, although in four of the States the acreage has increased and in the other four it has decreased.

KENTUCKY AND TENNESSEE.

Kentucky and Tennessee, each with an acreage fairly constant, show an increase in yield per acre, while West Virginia has remained about constant.

OHIO, WEST VIRGINIA, AND INDIANA.

Ohio, West Virginia, and Indiana, with an increasing acreage for the first three decades, represented by the figures 3,503,127, 5,283,871, 5,530,392, and 4,588,086, show a slight increase in fertility, represented by the figures 11.6, 13.3, 12.4, and 13.1.

TEXAS AND ARKANSAS.

Of the other large wheat-producing States, Texas, with an increase of acreage from 119,340 acres in the first decade to 993,206 in the last, has remained practically constant in yield per acre, while Arkansas, with a practically constant acreage, has increased during the past thirty years.

CALIFORNIA AND OREGON.

California, with a fairly constant acreage, is the only one of the States showing an apparent decline in yield per acre, the figures for the several decades being 14.6, 12.9, 12.7, and 11.6. But, it should be observed that during the last decade there occurred two of the lowest yields on record, while in the last year of the last decade the yield per acre was 17.1 bushels, exceeded only by the crop of 1868 of 20 bushels and that of 1870 of 19 bushels. The two middle decades in many of the States show lower yields than the first and last, which indeed is shown in the adjoining State of Oregon, where the yield by decades is 18.6, 17.1, 17.1, and 18.7, and the fact that in the last year of the last decade a yield was obtained exceeded only by two others, makes it seem quite probable that with more data covering a longer period of time California would show no exception to the rule of a slight but gradual increase in productivity as measured by the yield per acre of wheat.

The following table gives the data for the States having records covering less than forty-year periods and more than twenty years, and with not less than five years in each decade:

Average yield of wheat, in bushels per acre, in States having twenty to forty year records.

State or Territory.	First decade.	Second decade.	Third decade.	Fourth decade.
Utah		[a] 17.5	18.8	23.5
Nevada	[b] 21.1	[b] 17.3	19.2	26.0
Wyoming		[a] 17.4	[c] 21.0	23.0
Idaho		[a] 16.9	19.2	23.8
Colorado		[b] 19.2	19.0	24.6
North Dakota		[a] 14.1	[c] 14.0	12.3
Montana		[a] 17.5	20.8	26.7
New Mexico		[a] 13.2	15.6	20.0
Arizona		[a] 13.8	16.2	21.8
Washington		[a] 16.5	17.7	23.3

[a] 5 years. [b] 7 years. [c] 6 years.

The data here are so incomplete in comparison with what has been given, and the question of irrigation in many of these States introduces so uncertain a factor, that the results will not be discussed; while for some of the other States, notably New Hampshire, Massachusetts, Connecticut, Rhode Island, South Dakota, Louisiana, and Florida, the data are so incomplete that no conclusions can be drawn.

If any conclusion is to be drawn from the statistics it can only be that the fertility of our soil, as measured by the average yield of wheat per acre, is increasing.

YIELD PER ACRE OF CORN IN THE UNITED STATES.

The average yield per acre of corn in the United States for the past forty years is 25.1 bushels, the figures for the four decades being 26.1, 24.8, 24.2, and 25.4. It is apparent that the period of forty years with its four decades is too short a time to eliminate or balance the great seasonal variations, and in the country as a whole as well as in the records from most of the States we get a yield above the average in the first and last decades and below the average in the two middle periods. It would appear, then, on the face of it that there has been no decline in fertility as measured by the yield per acre of corn, but it must be remembered that the acreage upon which the estimate of the yield is made has considerably increased, the figures for the several decades being 386,884,000, 634,089,000, 742,909,000, and 879,712,000.

As the estimated average yield per acre is based upon the actual acreage in corn, it is obvious that if the greater portion of this increased acreage occurred in the States having greater average yields than the country at large, the average yield of the United States would be increased, possibly to the extent of masking any change in the fertility, while, on the other hand, if the greatest increase in acreage occurred in the States having a lower average yield, the average yield per acre of the United States would be reduced, so that in themselves the figures above given show nothing as to any change in fertility of the soil of the United States. To arrive at any definite conclusion it will be necessary, as in the case of wheat, to consider the yield of individual States and of groups of States. It may be stated at the outset, however, that for two reasons the figures for corn do not lend themselves so well to a complete solution of this great question as do those for wheat. The average yields per acre of nearly all the States are considerably higher in the first and last decades than in the intervening twenty years, indicating probably profound and long continued seasonal variations.

The acreage in all but New York, Pennsylvania, and California of the large corn-producing States has increased considerably, and in only two of the smaller States, namely, Rhode Island and Maine, has there been a regular and obvious reduction in acreage, so that the influence of intelligent selection of lands to be taken up or abandoned for corn culture can not be considered. However, in the case of wheat it was shown that this had no apparent effect upon the average yields so far as could be determined from the statistics.

YIELD PER ACRE OF CORN IN THE SEVERAL STATES.

The following table gives the States for which forty consecutive years' records are furnished by the Bureau of Statistics, excepting California, which has thirty-nine years' record, arranged according to their average yields per acre:

Average yield of corn, in bushels per acre, for forty years, 1866–1907.

State.	Yield.	State.	Yield.	State.	Yield.
New Hampshire	35.1	Michigan	30.8	Delaware	22.6
Vermont	35.1	Illinois	30.2	Tennessee	22.0
Massachusetts	34.5	Rhode Island	30.1	Arkansas	20.0
Pennsylvania	33.2	California	30.1	Texas	19.1
New Jersey	33.2	Minnesota	29.2	Virginia	19.0
Maine	32.9	Nebraska	28.7	Louisiana	16.7
Ohio	32.9	Missouri	28.3	Mississippi	15.0
Connecticut	32.2	Maryland	26.6	North Carolina	13.3
Iowa	32.2	Kentucky	26.1	Alabama	13.1
Indiana	31.5	West Virginia	25.3	Georgia	11.0
Wisconsin	31.3	Kansas	25.1	Florida	9.8
New York	30.8	United States	25.1	South Carolina	9.7

There are twenty-three States having the same or a higher average yield than the United States and twelve States having a lower yield.

It is obvious that the yield per acre remaining the same, any increase in acreage will have no effect on the average yield for the United States, while an increased acreage in Georgia would counterbalance an increase of nearly three times the acreage in Nebraska, on account of the disparity in the yield and the departure from the average. It has not been deemed wise, however, to attempt to arrive at conclusions as to a change of fertility by such a method of comparison.

NEW ENGLAND STATES.

The acreage in Maine and Rhode Island has materially decreased, while indications are that the yield per acre has slightly increased. The acreage of the four other States has remained fairly constant, while the figures indicate a slight decrease in the yield per acre in New Hampshire and Vermont and a slight increase in Massachusetts and Connecticut. The differences, however, are so slight, as compared with the fluctuations between the decades, that no safe conclusions can be drawn as to any change of fertility. Comparing the groups of States, as was done in the case of wheat, the acreage for the four decades was 2,469,000, 2,627,000, 2,169,000, and 1,951,000, while the relative yields for the four decades may be expressed by the figures[a] 32.6, 32.5, 34.4, and 34.2, indicating if anything a slight increase in fertility of the soils as measured by the yield per acre of corn.

NEW YORK, PENNSYLVANIA, AND NEW JERSEY.

The acreage in New York, Pennsylvania, and New Jersey, has varied but little in the forty years, and the average yields indicate neither an increase nor decrease.

MARYLAND, DELAWARE, AND VIRGINIA.

The relative yield in the four decades of Maryland, Delaware, and Virginia may be expressed by the figures 21.8, 21.0, 20.9, and 27.0; the total acreage being 16,145,000, 24,973,000, 28,038,000, and 26,-243,000.

NORTH CAROLINA, SOUTH CAROLINA, GEORGIA, FLORIDA, AND ALABAMA.

The relative yield for North Carolina, South Carolina, Georgia, Florida, and Alabama for the four decades may be expressed by the figures 12.3, 10.8, 11.4, and 11.3; the total acreage being 66,993,000, 86,117,000, 102,619,000, and 113,809,000.

OHIO, INDIANA, ILLINOIS, MICHIGAN, WISCONSIN, AND MINNESOTA.

The relative yield for Ohio, Indiana, Illinois, Michigan, Wisconsin, and Minnesota may be expressed by the figures 31.7, 30.2, 29.0, and 33.1; the acreage being 126,441,000, 177,378,000, 162,838,000, and 193,646,000.

So far the data do not permit one to say that there has been an increase in fertility as measured by the yield per acre of corn, save possibly in the New England States, and certainly there is no justification for saying there has been a decrease. We now come to a group of States, however, which show a decided decrease, although a full analysis of the original data does not justify such a conclusion.

NEBRASKA AND KANSAS.

The average yield of Nebraska and Kansas may be expressed by the figures 33.3, 32.5, 25.7, and 24.8. These two States show by far the greatest increase in corn acreage of any of the 35 States under con-

[a] These figures are straight averages of the yields per acre as fertility factors in which each State has equal weight. This method is only allowed when the acreage and yields per acre of all the States are of the same order or do not vary much. The weighted averages in this case, when the sums of the acres and of the bushels of all the States are used, are 33.1, 32.6, 34.9, 34.6, showing the same order of increase. The former method lends itself rather better for the purposes of this investigation.

sideration. The basis for the estimate of the average yield per acre in the last decade, namely, the acreage, was 700 per cent larger in Kansas and 2,500 per cent larger in Nebraska than in the first decade, yet we have in Nebraska the average yield of 32 bushels on 3,011,000 acres in the first decade to compare with the average yield of 27.8 bushels on 77,213,000 in the last decade, and nearly as great a disparity in the case of Kansas. The combined acreage for the four decades is 12,625,000, 63,621,000, 110,130,000, and 154,177,000.

However, taking the data as they stand, we find, in going back to the original data, three years of crop failure in Kansas in the third decade, the average yields being for 1887, 14.6 bushels; 1890, 15.6; and 1894, 11.2, the highest yield being in 1889, 35.3 bushels. In the last decade there were three years of very low yields, 1897, 18.0 bushels; 1898, 16.0; and 1901, 7.8. The last five years of the last decade show four years well above the average for the forty years, so that here again there is no apparent justification for assuming a decrease in the average fertility of the soil as measured by the yield of corn. Similarly, in the third decade, Nebraska shows a yield of only 6.0 bushels in 1890, while in the last decade are two very low yields and four out of the last five years show a considerably larger yield than the average for the forty years.

IOWA AND MISSOURI.

Adjoining Kansas and Nebraska on the east are the States of Iowa and Missouri, where there has likewise been a considerable increase in acreage, although not nearly so large as in the first-named States. The total acreage of the two States for the four decades is 58,188,000, 117,138,000, 141,778,000, and 148,721,000. The average yields may be expressed by the figures 31.5, 29.4, 30.3, and 30.2.

MISSISSIPPI, LOUISIANA, TEXAS, AND ARKANSAS.

The average yield of Mississippi, Louisiana, Texas, and Arkansas may be expressed by the figures 20.9, 17.2, 16.9, and 17.5; the total acreage being 40,408,000, 71,225,000, 91,561,000, and 110,791,000. Texas and Arkansas both show a large increase in acreage and a moderate decline in yield, but an analysis of the figures shows reasons for this in great seasonal variations, as in the case of Kansas and Nebraska, and it is not safe to conclude from the data that the fertility of the lands as measured by the yield per acre of corn of any one of these four States has declined. Considering the large increase in acreage and the wide variations in yield per acre due to climatic conditions, it would take a considerably longer period of observations to determine definitely the question of any change in fertility of the soils. In other words, it may reasonably be assumed that for the past forty years the fertility of the soils of this group of States has remained fairly constant.

CALIFORNIA.

The average yield for California may be expressed by the figures 37.4, 28.2, 29.9, and 29.9; the acreage being 326,006, 1,101,000, 1,127,000, and 562,000.

In the last half of the last decade, during four years the average yields were well above the average for the thirty-nine years and are comparable with the yields of the first decade, with the exception of the very large yields of 1868, 45 bushels; 1869, 41.4 bushels; and 1873, 41 bushels; so that it would not be safe to conclude that there has been any decline in the fertility in the soils of the State in the past thirty-nine years as measured by the yield per acre of corn as indicated by the average yields of the four decades, any more than it would be safe to assume an increase during the past thirty years as also indicated by the decade figures.

Summing up the data furnished by the Bureau of Statistics on the yield of corn per acre, it is unsafe to draw any conclusion other than that the fertility of the soil of the United States as measured by the yield per acre of corn has remained practically constant, with, if anything, a slight tendency to increase. The data are, however, much more difficult to draw conclusions from than in the case of wheat, partly because of the wide seasonal fluctuations and partly on account of the large increase in acreage in most of the larger corn States. The following table gives the percentage of increase in the acreage of the 24 States showing an increase, which displays at once the difficulty of drawing conclusions from figures where the basis of the figures which are to be compared has such wide variation:

Percentage of increase in corn acreage from 1866 to 1907 in the several States where material increase has occurred.

State.	Percentage of increase.	State.	Percentage of increase.	State.	Percentage of increase.
Nebraska	2,500	Missouri	130	Indiana	54
Kansas	700	United States	127	Mississippi	50
Texas	356	Michigan	124	Tennessee	49
Minnesota	469	Louisiana	121	Alabama	46
Arkansas	190	Virginia	87	Illinois	36
Iowa	179	South Carolina	85	Maryland	26
Florida	153	North Carolina	75	Ohio	21
Wisconsin	152	Georgia	72		
West Virginia	133	Kentucky	56		

With the full analysis of the data for the two important crops of wheat and corn, it seems unnecessary for the purpose of this report to discuss the data relating to oats, barley, rye, hay, buckwheat, potatoes, and cotton, especially as a casual observation of the data furnished by the Bureau of Statistics on these crops shows the same general facts and would add nothing new to this discussion. The only inference, therefore, which can be drawn from the statistics is that the productivity of the soils of the United States has not declined in the past forty years, but that on the contrary it has increased.

THE FERTILITY OF THE SOILS OF EUROPE AS MEASURED BY THE YIELD OF CROPS.

In considering so serious and fundamentally important a question as the possible loss of soil fertility and the wearing out of our soils, and in order to show conclusively from the data submitted by the

Bureau of Statistics on our crop yields that the common impression on this subject is erroneous, it is well to review the facts presented by the experience of other countries.

In the European countries are older agricultural soils than in the United States, in that they have been settled and have been developing their present agriculture for a thousand years or more, while many parts of our great West have seen all of their agricultural development in the past forty or fifty years, since the great transcontinental railway systems were established.

If the views which have been taught for the past seventy years be correct, that continued cropping gradually exhausts the soil and tends to make it unproductive through loss of mineral plant food, we should expect to find a marked and fundamental difference between the soils of the United States and the older soils of Europe, as shown either in the yield of crops or in the chemical composition of the soils. We will first review such data as are available regarding the yield of crops and then consider the chemical data.

The following is given as the yield per acre of wheat in bushels in several European countries and in the United States for the ten years (1897–1906) in the Yearbook of the Department of Agriculture for 1907, page 620:

Average yield of wheat, in bushels per acre, of various countries.

United Kingdom	32.2
Germany	28.0
France	19.8
Austria	17.8
Hungary	17.6
United States	13.8
Russia (European)	9.3

It is apparent that the older soils of Europe are producing more than the newer soils of the United States. Have they always done so, or are the yields increasing there as they are with us, and has the increase gone farther with the longer time and the greater population and the necessities incident to the larger number of people to support?

Kellermann has made a most exhaustive investigation and report upon the increase in crop production in Germany.[a] He gives the yields per acre of a large number of estates which have been handed down from father to son, some of the records going back to the middle of the sixteenth century. Three cases only will be given here, which show the general trend of the information he was able to gather.

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[a] Landw. Jahrb. 35, 289 (1906).

Yield of cereals in Schmatzfeld, Germany.

[Reduced to bushels per acre.]

Year.	Wheat.	Rye.	Barley.	Oats.
1552–1557	12.5	13.2	14.2	14.8
1660		12.8	8.3	12.3
1670	14.6	17.2	16.1	17.4
1822	18.7	24.3	33.7	26.2
1825	18.1	20.0	28.1	32.5
1830	18.7	21.2	35.6	46.2
1840	25.6	30.0	31.6	45.5
1850	28.7	33.1	39.3	50.1
1860	35.3	39.3	32.9	62.9
1870	27.6	20.4	43.8	46.6
1886	37.9	28.9	43.2	66.6
1887–1896	40.0	29.6	47.6	59.7
1897–1904	45.1	34.0	50.4	69.1

The period from 1552 to 1557, apparently the average for those years, gives a yield of wheat of 12.5 bushels per acre; in 1670 there is a record of 14.6 bushels; in 1822 of 18.7 bushels; in 1825 of 18.1 bushels; in 1840 of 25.6 bushels; in 1850 of 28.7 bushels; in 1860 of 35.3 bushels; in 1897 of 45.1 bushels; an increase in those three hundred years from 12.5 bushels in 1552 to 45.1 bushels in 1897, the record showing a regular increase with a few fluctuations which are probably due to seasonal conditions.

Rye has increased during the same time from 13.2 bushels in 1552 and 12.8 bushels in 1660 to 30 bushels in 1840 and 34 bushels in 1897.

Barley has increased from 14.2 bushels in 1552 or 8 bushels in 1660 to 16.1 bushels in 1670, and finally to 50.4 bushels in 1897.

Oats have increased from 14.8 bushels in 1552–1557, the first record, to 69.1 bushels in 1897–1904, which is the last record.

Yields of cereal crops on a second German estate, Rittergat Trebsen, near Leipzig.

[Reduced to bushels per acre.]

Year.	Wheat.	Rye.	Barley.	Oats.
1756–1765	26.41	15.91	14.25	23.03
1766–1775	13.25	12.33	21.71	23.48
1776–1785	16.63	14.47	20.44	23.45
1786–1795	13.98	13.67	16.77	19.16
1796–1800	13.89	15.36	15.16	17.90
1814–1816	15.28	15.68	25.41	25.72
1820–1822	16.90	19.14	18.28	26.36
1825–1834	21.04	21.63	30.19	31.83
1835–1844	33.40	27.92	36.66	46.54
1845–1849	25.51	28.75		56.25
1883–1892	27.03	23.06	30.95	44.64
1893–1894	29.85	28.36	30.95	54.74
1895–1899	35.85	30.45	35.39	51.15
1900–1904	36.14	32.52	43.23	57.80

From this estate apparently even more continuous records are given in five and ten year periods from 1756 to 1904. The average yield of wheat in the first period of which we have a record, 1756–1765, is 26 bushels; in the next period, 1766–1775, it is 13 bushels; and from that time a gradual increase up to 1900–1904, when it was 36 bushels. Rye increased similarly by regular steps from 15.91 bushels to 32.52 bushels. Barley from 14.25 bushels to 43.23 bushels. Oats from 23.03 bushels to 57.80 bushels.

Yield of cereals on the soils of Tellow.

[Reduced to bushels per acre.]

Year.	Wheat.	Rye.	Barley.	Oats.
1800–1810	21.15	14.64	19.80	17.22
1810–1820	20.02	11.76	20.92	13.44
1820–1830	23.25	17.76	21.29	14.84
1830–1840	18.82	15.04	16.37	13.86
1840–1850	23.10	19.84	20.83	27.58
1850–1855	26.40	23.12	32.75	33.46
1855–1860	25.27	24.16	27.71	34.44
1860–1865	29.77	30.48	37.85	44.52
1865–1870	27.45	26.48	36.17	55.72
1870–1875	29.92	28.32	35.71	51.38
1875–1880	28.12	24.32	29.38	39.48
1880–1885	25.57	25.12	36.45	45.08
1885–1894	35.70	29.52	41.06	43.96

On this estate from 1800 to 1894 in ten-year averages wheat increased from 21.15 to 35.70 bushels, rye from 14.64 to 29.52, barley from 19.8 to 41.06, and oats from 17.22 to 43.96.

Kellerman throughout cites many well-known authorities and refers to many sources of information, and concludes his article with this remarkable statement:

If we now make a brief survey of the results obtained in the foregoing, we must affirm that the development of the yields of cultivated soil since the beginning of the past century presents a very pleasing picture, not only that agriculture, by absolute addition to the acreage of 30 to 35 per cent and decrease in fallow from 35 to 4½ per cent, has tried to meet the growing needs of the nation for food, but above all that it has shown how to gain from the soil gradually 2½ times as much per unit of surface as formerly.

The same facts have been brought out by Steinbrück,[a] who cites many cases of individual farms from records going back for one hundred years or more.

The French minister of agriculture[b] gives the average yield per acre of the principal cereal crops in France from 1815 to 1876, which, reduced to bushels per acre and ten-year averages, is as follows:

Yield of cereals in France.

[Reduced to bushels[c] per acre.]

Year.	Wheat.	Rye.	Barley.	Oats.
1815–1824	11.86	10.10	14.45	17.12
1825–1834	13.44	12.34	14.64	17.78
1835–1844	14.30	13.01	15.92	20.10
1845–1854	15.14	13.09	18.12	22.33
1855–1864	15.90	14.11	19.90	24.93
1865–1874	15.81	14.65	19.75	24.49
1875–1876	16.60	15.71	19.00	23.61

[a] Der Boden und die landwirtschaftlichen Verhältnisse des Preussischen Staates, vol. 7, p. 799 (1906), edited by August Meitzen.

[b] Bull. Min. Agr. Comm. France. Récoltes des Céréales et des Pommes de Terre de 1815 à 1876, pp. 456–459 (1878).

[c] Bushels of capacity. Statistics for the ten years 1897–1906 indicate that the average weight of a bushel of wheat in France is 60.0 pounds, of a bushel of rye 56.1 pounds, of a bushel of barley 49.6 pounds, and of a bushel of oats 36.5 pounds. The statistics for France on p. 39 are in the bushels of weight customarily employed in the United States (wheat 60 pounds, rye and corn 56 pounds, barley 48 pounds, oats 32 pounds). The difference is greatest in oats, the average yield of which, as given in this table, is on a basis some 14 per cent lower than in tables on p. 39, covering later years. Comparisons between these tables should not be made without making allowance for this.

Wheat has increased from 11.86 to 16.60 bushels; rye, from 10.1 to 15.7; barley, from 14.4 to 19; oats, from 17.12 to 23.61. The great increase in the yield of cereal crops for France is prior to 1860.

CEREAL PRODUCTION OF EUROPE.

Quite recently the Bureau of Statistics of this department has published a report on the cereal production of Europe [a] for the past twenty years or so. (See Appendix A.)

The following table as given in this bulletin summarizes the yield per acre as given in detail in the tables in the appendix to this report, in five-year periods.

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[a] Cereal production of Europe, by Frank R. Rutter, editorial assistant, Bureau of Statistics, Bull. 68 (1908).

Average annual yield of grain, by countries and by five-year periods.

Country.	Wheat.				Rye.				Barley.				Oats.				Corn.			
	1886–1890.	1891–1895.	1896–1900.	1901–1905.	1886–1890.	1891–1895.	1896–1900.	1901–1905.	1886–1890.	1891–1895.	1896–1900.	1901–1905.	1886–1890.	1891–1895.	1896–1900.	1901–1905.	1886–1890.	1891–1895.	1896–1900.	1901–1905.
Austria-Hungary:	*Bu.*	*Bu*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
Austria	15.9	16.1	16.3	18.5	15.8	15.7	15.9	18.6	20.1	21.3	20.8	23.7	24.3	25.1	25.5	26.7	19.5	19.9	18.9	18.5
Hungary	17.6	19.1	16.7	17.9	15.6	16.9	16.3	17.6	17.9	21.8	22.1	22.5	20.6	25.7	30.1	30.1	18.5	23.2	22.6	19.3
Winter	17.9	19.3	16.8	18.0	15.7	17.0	16.4	17.7	18.2	20.9	20.9	22.3	......	......	......	......	......	......	......	......
Spring	12.6	14.8	13.0	13.2	13.0	14.9	13.8	13.6	17.9	21.9	22.2	22.5	......	......	......	......	......	......	......	......
Belgium:																				
Winter	27.1	27.8	29.7	} 34.0	25.4	28.9	30.1	34.0	40.8	40.4	43.6	52.0	} 49.8	50.0	56.8	64.7	......	......	......	......
Spring	21.8	24.5	a 22.7						33.6	33.7	35.8	41.0								
Denmark	35.8	38.7	41.0	40.2	24.6	26.7	25.8	26.8	29.7	30.4	30.9	34.0	32.0	33.8	35.5	35.9	......	......	......	......
France	17.8	17.7	19.3	20.2	16.4	17.9	17.1	16.8	21.9	21.5	22.5	24.0	30.2	28.7	30.1	32.0	19.3	19.1	19.0	19.4
Germany	20.3	23.3	27.0	28.2	16.0	19.9	23.0	24.9	24.0	28.9	l 30.7	......								
Winter	21.4	23.5	27.3	28.1	16.1	20.0	23.2	25.1	29.0	33.8	l 37.8	......	} 33.2	37.7	45.0	47.1	......	......	......	......
Spring	17.8	21.3	a 23.3	28.0	12.1	15.7	16.8	17.5	23.9	28.8	31.8	34.3								
Italy	b 12.1	11.2	c 12.8	13.1	b 12.7	12.3	......	......	b 13.4	10.8	c 13.2	......	b 17.0	16.2	......	......	b 15.9	15.1	c 16.5	20.2
Netherlands	28.1	27.2	29.8	32.5	22.6	23.4	24.9	25.8	42.4	43.1	45.2	48.0								
Winter	......	d 28.0	29.8	32.4	......	d 24.7	24.9	25.9	46.4	47.5	48.0	50.7	} 45.9	46.1	50.8	53.9	......	......	......	......
Spring	......	d 28.3	30.0	35.3	......	d 20.8	20.3	22.8	34.7	35.7	38.1	40.8								
Norway	24.3	27.9	26.7	e 22.2	27.9	27.8	27.7	25.8	33.0	33.0	34.5	28.9	40.6	44.4	41.0	33.9	......	......	......	......
Roumania	15.3	16.2	13.1	18.3	13.8	16.1	13.4	18.7	13.3	17.0	13.7	18.5	18.0	18.5	16.0	23.0	14.4	14.6	14.6	13.3
Russia (total)	......	f 10.3	8.7	10.3	......	f 12.0	11.2	11.7												
Winter	......	f 12.9	10.6	13.9	......	f 12.1	11.3	11.8	}	f 14.4	12.4	14.2	......	f 20.8	18.9	20.0	......	f 11.8	13.5	13.7
Spring	......	f 9.2	8.0	9.0	......	f 10.2	9.4	9.5												
Russia, European	g 7.9	8.9	8.4	10.3	g 9.5	10.3	11.3	h 12.2												
Winter	g 11.1	11.2	10.6	13.9	b 9.4	10.4	11.3	11.8	} g 11.0	13.7	12.3	14.2	g 15.1	17.7	18.6	20.0	......	m 13.9	13.5	13.6
Spring	g 6.8	7.9	7.5	8.8	b 4.8	8.0	8.2	8.9												
Servia	......	i 11.1	j 13.9	12.6	......	i 8.9	j 13.5	9.9												
Winter	......	i 11.4	k 15.2	h 12.8	......	i 10.8	k 14.6	h 11.2	}	i 11.1	j 16.4	13.9	......	i 12.5	j 24.0	14.7	......	i 13.8	j 22.2	13.4
Spring	......	i 8.4	k 10.8	h 7.9	......	i 6.8	k 13.1	h 8.2												
Spain	b 8.8	d 11.6	10.8	13.0	b 10.5	g 11.6	10.9	12.6	b 10.1	f 20.4	16.1	18.9	......	f 15.3	18.0	20.5	b 24.3	f 21.4	19.1	22.5
Sweden	b 23.2	23.5	26.1	25.0	b 22.4	21.5	21.9	22.2												
Winter	b 23.4	23.7	26.5	25.3	b 22.5	21.6	22.0	22.3	} b 27.0	25.0	25.2	24.6	b 32.0	29.8	28.1	27.7	......	......	......	......
Spring	b 20.6	21.3	21.2	22.0	b 16.3	17.2	16.7	17.5												
United Kingdom	30.4	29.0	32.8	31.7	......	......	......	......	33.9	34.2	35.0	34.3	41.8	43.5	43.4	44.7	......	......	......	......
Great Britain	30.4	29.0	32.7	31.7	......	......	......	......	33.7	33.8	34.6	33.6	39.3	39.6	39.8	40.5	......	......	......	......
Ireland	27.9	30.7	32.0	34.6	24.1	26.2	24.8	27.1	36.4	39.7	40.2	42.2	47.6	53.3	53.0	56.7	......	......	......	......

a Average, 1896–1899. *b* 1890. *c* 1896. *d* Average, 1892–1895. *e* Average, 1902–1905. *f* Average, 1894–1895. *g* Average, 1888–1890. *h* Average, 1901–1904. *i* 1893. *j* Average 1897–1900. *k* Average, 1897 and 1900. *l* Average, 1896–1898. *m* Average, 1893–1895.

Commenting on this data Rutter has the following to say:

AVERAGE YIELD OF GRAIN.

Wheat.—On comparing the area under wheat in northwestern Europe in 1905 with the average crop during 1901–1905, it appears that the average yield per acre exceeds 25 bushels; in southwestern Europe the average yield is only 16 bushels per acre, and in eastern Europe but 12 bushels. For Europe as a whole the average yield is slightly under 14 bushels per acre.

It appears, therefore, that the average yield per acre is highest where wheat culture is least generally practiced and where the acreage under grain shows the smallest increase. In other words, the extension of the wheat area is most marked where the average yield per acre is lowest.

This condition holds true as regards individual countries as well as the larger divisions of Europe. The United Kingdom, Belgium, the Netherlands, and Denmark are at the same time the four countries in which the wheat acreage during the last twenty years has shown the largest reduction and the four countries which show the largest yield per acre. In each of these countries the acreage under wheat has fallen at least one-fifth in amount, while in each of them over 30 bushels per acre has been harvested on an average during the last five years.

At the other end of the series stands European Russia, in which the increase in acreage during the twenty years was no less than 60 per cent, while the average yield per acre was little more than 10 bushels.

Between these two extremes the relation pointed out between yield and acreage has been by no means so constant, but the divergence is not sufficiently marked to affect the general correspondence. In Sweden, for instance, the acreage under wheat has shown a considerable increase, while the average yield per acre is high, nearly 25 bushels per acre. On the other hand, in Spain the low average yield, 13 bushels per acre, has been accompanied by a small increase in the acreage and the crop.

That the extent of wheat culture should vary inversely as the average yield per acre, or, in other words, that where the results are best the smallest areas are devoted to wheat, seems at first sight paradoxical. It must be remembered that a high average yield, such as shown in the Teutonic countries of Europe, presupposes intelligence on the part of the farmers and valuable land justifying a large outlay of labor and capital. These conditions are much more favorable to the growth of crops requiring intensive cultivation than to grain crops, which give the highest profit when grown on new land on a large scale. Low average yields, if obtained at a low cost of production, produce a greater aggregate profit than can be obtained from grain crops on the smaller tracts in northwestern Europe, where the high price of land necessitates its use in intensive culture. (See Table 5. This table contains unweighted averages of the yearly average yields shown later in the detailed tables.)

Rye.—The yield of rye is highest in Belgium, where during the five years 1901–1905 an average of 34 bushels per acre was obtained. After Belgium come Ireland, Denmark, the Netherlands, Norway, and Germany, in all of which an average yield of from 25 to 27 bushels per acre was obtained. The lowest average yield per acre during the same years was obtained in Servia, 10 bushels per acre, while in European Russia the average yield was slightly more than 10 bushels and in Spain 13 bushels per acre.

Barley.—Of barley, as of rye, the highest average yield per acre during the last five years was obtained in Belgium, in which more than 50 bushels per acre was grown on an average, while the average yield of winter barley alone was 52 bushels per acre. In the Netherlands the average yield was only slightly lower, amounting to 51 bushels per acre for winter barley and 48 bushels for barley of both kinds. Outside of these two countries barley is grown principally as a spring crop; and if that variety alone be considered, Ireland, with 42 bushels per acre, shows the highest average yield. In Germany, Denmark, and Great Britain the average yield per acre is 34 bushels. The lowest average yields per acre recorded are shown by the statistics of European Russia and Servia, according to which but 14 bushels per acre were raised during each of the five years under review.

Oats.—Belgium records an average yield of oats during the five years 1901–1905 of no less than 65 bushels per acre, while Ireland produced 57 bushels and the Netherlands 54 bushels. The smallest average yield per acre recorded is that of Servia, where only 15 bushels were obtained, and European Russia, with 20 bushels.

Corn.—The variations in the average yield per acre of corn are far less marked than the variations in the grains already considered. The almost total absence of its culture from any country included in the northwestern division eliminates the very countries where intensive culture is practiced. The highest yield recorded in 1901–1905 was 22½ bushels per acre in Spain, while the lowest, between 13 and 14 bushels, was obtained in Roumania, Servia, and European Russia.

It is evident from an inspection of all available statistics here cited that the fertility of the older soils of Europe as measured by the yield of cereal crops is fully as great or greater than that of the soils of the United States, and also that the yields have very materially increased during the past century, seemingly much faster than in this country. So far as can be judged from the rather meager records of early days, the yield of cereal crops in the older settled countries of northern Europe at or before the beginning of the last century was not very different from the yields in Russia (still sparsely settled) and in the United States at the present time.

CHEMICAL COMPOSITION OF THE SOILS OF EUROPE AS COMPARED WITH THOSE OF THE UNITED STATES.

It remains now to see if the longer occupation and larger yields of the European countries have materially affected the chemical composition of the soils and sensibly reduced the amount of the mineral plant-food elements. Rocks vary greatly in their ultimate chemical composition, according as one or more of the common minerals predominates, which also gives the essential character to the rock. Soils vary in ultimate chemical composition as the rocks from which they are formed vary and, according to the mode of their formation, are generally more complicated than the rocks with respect to the minerals they contain. It is as difficult, therefore, to compare soils from the chemical composition, unless the type is given, as it would be to compare rocks from the data alone unless the character of the rock were known. As the science of soil classification and soil surveying is new and not on an international basis, it is impossible to compare soils from different countries in any classified or systematic way. The best that can be done, therefore, is to present all the available analyses from a few countries and see if the range in composition is about the same in one as in the others. This method has been followed in the present report, and without attempting to make a selection, and recognizing the unsatisfactory nature of averages with such variable data, all analyses of soil by acid digestion available in the literature in regard to Great Britain, France, Germany, and the United States, in the past eighteen years are given in Appendix B accompanying this report, embracing 1,945 analyses from the United States, 278 from Great Britain, 1,565 from France, and 444 from Germany, or a total of 4,232 analyses.

It must be remembered that the aggregate area of the three countries selected include only a part of the continent of Europe. The total area of Europe is estimated at 3,550,000 square miles, according to Rohrbach, and 3,760,000 according to Wagner-Supan; of continental United States at 2,974,159 (land area) square miles. The area in square miles of the European countries selected for a comparison of the chemical composition of the soil with those of the United States covers only about one-sixth of the continent. The areas, as given in the Statesman's Yearbook, are as follows:

Great Britain and Ireland:		
England	50, 848	
Wales	7, 467	
Scotland	30, 405	
Ireland	32, 360	
		121, 080
Germany		208, 780
France		207, 054

The land area in square miles of some of our own States with which these figures might perhaps be compared are:

Texas	262, 398
California	156, 092
Minnesota	80, 858
Missouri	68, 727
Illinois	56, 002
Alabama	51, 279
Florida	54, 861
New York	47, 654
Pennsylvania	44, 832

The method of sampling the soil of a field is not refined, and the chemical methods of determining the small amounts of potash, phosphoric acid, lime, and magnesia in such samples give such variable results, even with the same method on the same sample with the same or with different analysts, that it is unsafe to draw conclusions from slight differences in actual amounts shown even when the differences are proportionally large.[a] It is safer to consider the general range in values for the different localities.

One can not but conclude from the inspection of these data that the chemical composition of the older and longer-used soils of Europe, as regards the principal mineral plant-food elements, is essentially the same as that of the soils of our own country, thus disposing of the fallacious doctrine that soils wear out through loss of plant food by continuous cropping, at least in finite time and to an extent which can be recognized by our methods of observation.

The differences in the chemical composition of the mineral portion of soils as shown by the analyses can not be correlated in general with differences in crop yields; in other words, the fault lies not with the

[a] Note the results of the analyses of 73 samples from a field of approximately 250 hectares (617 acres) in St. Viand, France, given in one of the tables in the appendix to this report, where the potash varies from .07 to .51 per cent; phosphoric acid from .03 to .10; and lime from .05 to .47 per cent. Of the 1,565 analyses reported from France there are only 69 cases, and most of these in one canton, where the potash falls below .07 per cent—the minimum found on this field—and 51 cases where it goes above .51 per cent. So that it may be said that the variation in the composition of the soil in this single field, as regards potash, is almost as great as the variation in the soils of France.

For a number of years it has been the practice for the referee on soils of the Association of Official Agricultural Chemists to submit carefully prepared samples of soils to various analysts for analysis according to prescribed instrucmethods of analysis, but rather with the uncertainty regarding the interpretation of such results. There are, in fact, no general significant differences in soil composition as regards the mineral matter, but there are, as we shall see, great and significant differences in the chemical composition of the organic constituents of soils.

An examination of the records of the analyses from 592 localities in the Department of Aisne, France, shows that in 407 cases, or 68 per cent, phosphoric acid is the same or higher in the soil than in the subsoil, and in 278 cases, or 47 per cent, potash is the same or higher in the soil than in the subsoil. The same holds true in general of the soils of this country.

The researches of several experiment stations throughout the world and the investigation of our engineers on the amount of material

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tions as to methods of procedure. The following tables give a few of the results of these comparative tests:

Soil sample No. 2.

[Provisional method: Thirty-six hours' digestion.]

Analyst.	K_2O.	Na_2O.	P_2O_5.	CaO.	MgO.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
A	....	....	0.429	....	....
B	0.397	0.76	.480	0.585	0.519
C	.470	.155	.486	.521	.407
D [a]	.275	.280	.580	.360	.360
D [b]	.340	.140	.560	.410	.390
D [c]	.450	.140	.530	.430	.400
E [d]	.330	.125	.600	.430	.375
F	.49	....	.16	.60	....
G	.44	....	.48	....	....
H	.48	....	.47	....	....

[a] Digestion in Snyder flask.
[b] In platinum flask and condenser.
[c] In platinum bottle, stoppered.
[d] Reported as dried at 110° C., figured to original soil by reporter.

(Bulletin No. 43, Bureau of Chemistry (1894), p. 33.)

Phosphoric acid and potash calculated as per cent of the dried fine earth.

[Official method: Ten hours' digestion in HCl of 1.115 sp. gr.]

Analyst.	K_2O. Sample No.—				P_2O_5. Sample No.—			
	1.	2.	3.	4.	1.	2.	3.	4.
A	0.359	0.154	....	....	0.447	0.268	0.409	0.230
B	....	....	....	....	.420	.210	.462	.244
C	.345	.112	0.380	0.04	.430	.117	.449	.095
D	.354	.235	.396	.225	.324	.201	.421	.267
E	.260	....	....	....	.510	....	....	....
F [a]	.373	.179	.365	.175	.451	.172	.396	.193
F [b]	....	....	....	....	.412	.185	.383	.190
G	.210	.130	.220	.100	.460	.210	.500	.220
H	.304	.125	.286	.158	.425	.163	.422	.176

[a] Gravimetric. [b] Volumetric.

(Bulletin No. 47, Bureau of Chemistry (1896), p. 36.)

carried in solution and in suspension in our principal rivers and by the wind establishes the fact, as above stated, that loss through normal leaching removes far more mineral plant food than do cultivated crops. In cropping soils, therefore, and removing the crop from the land we remove an inconsiderable amount of mineral material compared with normal losses to which the soil is adjusted through natural laws which are now for the first time being understood.

It seems safe to assume from the foregoing data that the soil (given a sufficiency of water to supply growing plants) is the one indestructible, immutable asset that the nation has. It is the one resource which can not be exhausted—that can not be used up. If the coal and iron give out, the soil can be depended upon to produce food, light, heat, and habitation not only for the present population, but for an enormously larger one. This will become more evident as we discuss the function of the soil as related to crop production. It may be abused and the yield will quickly decline, and it is the large num-

Phosphorus soluble in fifth normal nitric acid.

[Parts per million in dry soil.]

Analyst.	No. 1.	No. 2.	No. 3.	No. 4.
A [a]	15.0	8.0	5.0	158.0
A	22.0	15.0	10.0	175.0
A [b]	18.0	10.0	5.7	158.0
A	18.0	11.0	6.0	158.0
A [c]	14.4	7.4	4.4	165.5
A	14.0	7.4	4.8	162.0
B	13.4	5.8	3.6	155.5
B	12.9	6.1	2.8	154.5
C	14.0	7.7	3.1	163.4
D	10.6	5.7	3.6	145.6
D	......	5.6	......	......
E	16.6	9.7	6.4	157.1
F	31.7	15.2	25.5	167.4
G	14.4	7.8	4.8	165.4
G	14.6	7.8	4.8	166.0

[a] Work done according to directions sent out.
[b] Baking of residual omitted.
[c] Baking omitted and phosphorus determined by Kentucky method.

(Bulletin No. 105, Bureau of Chemistry (1907), p. 144.)

Potassium soluble in fifth normal nitric acid by official method.

[Parts per million in dry soil.]

Analyst.	No. 1.	No. 2.	No. 3.	No. 4.
A	99.2	130.0	141.7	236.0
A	88.7	135.9	139.8	233.1
B	113.0	128.0	188.0	276.0
C	95.5	127.9	135.5	234.4
D	89.3	107.9	120.8	189.1
E	91.3	136.0	142.5	244.9
E	96.1	133.8	139.8	249.9

(Bulletin No. 105, Bureau of Chemistry (1907), p. 144.)

ber of such individual failures that forms the basis for the impression that soils wear out by continuous cropping through loss of plant food. We do not notice so clearly the compensating successes which, as we have seen on the average for the past forty years, have rather more than counterbalanced the failures. To produce its best the soil must be thoroughly understood and properly handled. The proper handling may come from long experience on the same soil, as with the English and German farmers, but even then they have benefited greatly by the scientific work that has been done by individuals and experiment stations. In our own country we have not the general experience gained by long residence on the same land. We have not had the pressing necessity for intensive cultivation, and we have, therefore, more to learn and benefit from a knowledge of the nature of the soil, as we are but beginning to feel the necessity of more intelligent methods, of more intensive agriculture. If our nation can in the present century do what Kellermann asserts the German nation did in the past century, increase the productive capacity of the soils 2½ times, it will be a notable achievement and one well worth the effort. There seems to be no reason why this can not be done. It must be a national effort participated in by all the people, as upon it depends the very foundation of the continued prosperity and integrity of the nation.

THE FUNCTION OF THE SOIL AS A MEDIUM FOR PLANT GROWTH.

The soil is essentially a mixture of a large variety of mineral fragments. Nearly all agricultural lands contain most of the common rock-forming minerals and these minerals contain the mineral plant food elements. These minerals are slightly soluble in water, sufficiently soluble to maintain a solution of about 25 parts per million of potassium and about 8 parts per million of phosphoric acid. This strength of solution is amply sufficient for plants to draw their nourishment from, provided the supply is maintained as the plant withdraws sufficient for its needs. This constant supply is assured by the rapidity with which minerals dissolve—a saturated, although a very dilute solution being obtained after a few minutes contact of the soil and water. The supply, or rather the concentration, is maintained nearly constant by the additional wonderful power the soil has of absorbing mineral matter and the large variety of mineral species, so that the composition and concentration of the soil moisture does not vary greatly for light sands, loams, or heavy clays, nor for what we recognize as productive and unproductive soils.

In 1903 the Bureau of Soils, by very delicate methods, made a large number of analyses of the water-soluble material in fields of growing crops in both good and poor condition to see if any evidence could be found of any temporary exhaustion due to the absorption of mineral matter by the crops more rapidly than the rate of solution, and to ascertain also if constant differences were shown between the productive soils and soils of low productivity. The results, published in Bulletin 22 of this bureau, are restated in Appendix C of this report.

It will be remembered that while the methods of analyses are accurate to within 1 or 2 parts per million, and in the case of potash especially much more accurate than this, on different portions of the same extract of the soil there is sufficient variation in the soil of a field to account for many of the differences shown, especially where the variations appear to be erratic and uneven.

It seems evident from these results and other investigations of the bureau that there is no significant difference in the composition of the soil moisture in good and poor soils, and not even a significant temporary exhaustion of the average soluble mineral content of the soil during the crop season with the crop actually growing in the field. Moreover, the soluble mineral content has generally been found to be as high as or higher in the soil than in the subsoil. Summing up the results of modern investigations, it may be said that soil will not, in general, be worn out or exhausted so far as mineral plant food elements are concerned until most of the minerals of the soils have been dissolved and carried away, which is not conceivable in finite time under natural conditions. It is a fact recognized since the earliest historic times, referred to by many of the old Latin writers and familiar to us all in this country at the present time, that soils differ greatly in productivity and that the productivity of any particular farm or field may decline very markedly and very rapidly. It is no uncommon experience to see a farm, which has been well tilled and kept up to a high state of productivity for many years, rapidly decline when turned over to tenant farmers. Such changes attract the eye in the marked comparison with neighboring crops, dilapidated farm buildings, and general discontent of the less successful man. When the converse of this occurs and these lands are taken up and improved, these differences disappear and the change is less likely to be noted, or, if noted, soon forgotten. It is the same with sickness or disaster to the individual or to the community or to the nation, the years of even success fail to impress the mind as do the seasons of losses and troubles, so that it will come to many as a matter of surprise that on the whole our soils are more productive and that the available plant food supply shows no sign of wearing out. We have, however, a duty to the individual as well as to the nation, especially as in this case where a slight turn from failure to success of many individuals will elevate the nation in its commercial position in the world, so it behooves us to see why it is that many individuals fail to secure from the soil adequate returns, as measured by the returns secured by many other individuals on similar soils, and then to see why one part of our nation secures larger returns of necessary crops than other portions, and to learn if these matters may be equalized.

It is recognized throughout the civilized world that it is better to depend upon proper sanitary conditions to prevent and even to cure most diseases than upon drugs. It is recognized by animal breeders and animal users that sanitation is of the utmost importance; we recognize that fish in our aquarium, that yeast for commercial industries, that bacteria propagated for useful as well as for scientific purposes can only be kept alive and in condition if the products of their own life processes be removed or neutralized from time to time. Our plants are living organisms fixed in position in the soil during life, and like all other living organisms break down as well as build up organic bodies and give off or leave waste products in the soil. Such products appear to be generally harmful to the same species of plant following immediately after a first crop has been removed.

Moreover, this waste matter is further changed by soil organisms, direct oxidation processes, or by plant roots themselves into other degradation products, and finally in our best soils into the material generally harmless to plants which we recognize under the general term of humus. This is probably the complete and ideal form of soil sanitation, but it appears that this change does not proceed normally along such ideal lines in all soils or so as to leave them in their best condition for following crops, and as cultivation and cropping have much to do with these soil changes we are liable, through ill-adapted methods of management, to make matters worse instead of better as time goes on. Intermediate products of plant metabolism are left in the soil in forms, other than humus bodies, which are toxic to plants. Some such organic bodies have been separated from soils by this bureau and found to be toxic to some plants and nontoxic or even stimulating to other plants. Organic bodies of known composition, separated from wheat-sick soils and originated in the soil during the growth of successive crops of wheat, are toxic to wheat plants but not so to cowpeas. Similarly, organic bodies from cowpea-sick soils and formed in the soil during the growth of successive crops of cowpeas are toxic to cowpeas but not so to wheat. After cowpeas have been grown on the wheat-sick soils these bodies, associated with the unfavorable conditions for wheat, are found to have disappeared in whole or in part, and following the cowpeas wheat can again be produced, and so with other crops. Thus we have a logical and demonstrable reason for crop rotation.

Furthermore, lime, nitrate of soda, and certain organic matters such as the green parts of fresh cowpeas, stable manure, and in general organic matters rich in protein material, in decomposing in the soil react on certain of these toxic bodies and change or destroy them, thus improving the soil for subsequent crops. Potash and phosphoric acid appear to act with similar effect, although the action is less well understood. We have here probably one of the principal reasons, and a demonstrable one, for the action of fertilizers and manures in improving the sanitary conditions of the soil.

With this brief statement of the function of the soil as a medium of plant growth, we will turn now to the consideration of the differences in yields of any particular crop on different soils and in various sections of the United States. In the humid portion of the eastern United States, with the same kind of soil material, differing only in texture and water content, the distribution of profitable crops is largely determined by the texture of the soil. On the light sandy members of the series we have conditions favorable to certain fruits and early truck crops. As the texture becomes heavier we find conditions more favorable successively to corn, wheat, and hay grasses. This distribution is typically shown, for example, on the limestone soils of the valley of Virginia. In the Middle West, with a smaller rainfall, we find our best corn soils heavier than the best wheat lands. On the Pacific coast, and in general in the arid and semiarid portion of the country, with and without irrigation, this influence of texture largely disappears.

It appears that this influence of texture is not due to a mere difference in the supply of moisture maintained for the crop, but is due to chemical processes of reduction of the excreta and the remains of plants, which processes are affected both by the amount of moisture in the soil and the temperature.

While it is permissible to judge of the increase or decrease of soil fertility from long-time records of the yield per acre of any crop on the same field or of the same State when the acreage has remained fairly constant, as has been done in the first part of this report, it is not fair to assume that the average yield of about 16 bushels of wheat in New York and about 7 bushels in North Carolina, South Carolina, Georgia, and Alabama, or of about 30 bushels of corn in New York, and 11 or 12 bushels in the latter States, shows that the fertility of the New York soils in general is higher than the fertility of the other States, for, measured in other crops, the reverse might be shown. The figures do show, however, that so far as grain production is concerned the soil conditions in New York are more favorable than those of the South. This does not appear to be so much the effect of climate on the plant as of the plant's effect on the soil, as may be shown in a variety of ways. The same difference in yield of the cereal crops is shown in the countries of the north and south of Europe as in our own northern and southern States.

The largest yield of corn per acre on record (209 bushels) was on a trial acre in South Carolina, where the average yield is but 9.7 bushels, and very large yields are reported where a new method of culture is being tried of checking the vegetative growth with the toxic effect of weeds in their early stages of growth, followed by thorough cultivation and judicious fertilization.

The subsoil is generally toxic to crops in the humid southern States, but is as a rule equally as productive as the top soil under the arid climate of the West. There is every reason to believe that other varieties of our grain crops may be originated through selection which will be better adapted to southern soil conditions than those we now have, or that methods of culture may be devised which will permit of a much larger yield of grain in the Southern States than we now obtain.

One of the most interesting cases which appears to show the influence of the climate on the soil as a medium of plant growth is the case of the alfalfa crop. Adapted to almost all types of soil west of the Mississippi River under moisture conditions suitable to other crops, it has almost universally failed in the soils of the humid Eastern and Southern States, with two notable exceptions. One of these is the Dunkirk stony loam of New York, and the other the Houston clay extending from Alabama to Texas. The failure in the East is not due to lack of plant food. Inoculating the soil with the specific alfalfa bacteria does not insure success, nor can failure be attributed to the influence of climate on the crop, as there is no greater range of climate in the East than in northern New York and southern Alabama where the plant grows successfully on two different types of soil.

The following interesting article appeared in a recent number of "The Southern Planter:"

Alfalfa is undoubtedly a splendid forage plant where it will thrive without undue attention from man; it may be said to be the backbone of far western agriculture; but, like many other promising field crops, it should be studied with reference to soil and locality before extensive planting. A great many eastern farmers have failed ignominiously with alfalfa, and on a large scale, when a little less enthusiasm and a little more careful testing would have been the part of wisdom.

"West of the one hundredth meridian," said Professor Spillman, the agriculturist in charge of Farm Management, of the Department of Agriculture, in answer to the inquiry as to the department's present knowledge of alfalfa, "character of soil is but little considered in growing alfalfa; it will thrive anywhere that there is water. East of that line the plant is very discriminating as to its food. Wide experiments have been made by the various experiment stations and the Department of Agriculture all over the East, and in only a few circumscribed localities does it 'grow as a weed.' In some sections of the South, in a small limestone region of New York and southern Vermont, and in a few other scattered localities it grows readily, while it also does very well in parts of Wisconsin, Minnesota, and Illinois. But thousands of alfalfa fields in all the Eastern States have failed, and, while it is now known that alfalfa can be grown on these fields, the cost is, in the majority of soils, prohibitive.

"* * * It should not be expected that in the East the plant will endure and thrive twenty or thirty years as it does in the West," continued Professor Spillman. "If it would, the first cost of securing a good stand, however great, would be an inconsiderable quantity; but even where a good stand is secured the usual life of the field is, on lighter soils, one or two years, ranging up to five years on heavy, rich soils, with as high as three cuts per year, except in the specially adapted localities above mentionel."

It is an interesting fact developed by the Soil Survey that two soil types extending through different climatic regions best adapted respectively to corn and wheat in one locality will show the reverse adaptation under different climatic conditions. In the progress of the Soil Survey, the bureau has mapped 122 types of loam soils in the United States. About 58 per cent of the total acreage of these soils should be given first rank in the production of some one or more of our staple crops, about 26 per cent medium rank, and about 16 per cent low rank. They all have approximately the same texture, although they differ in the character of the soil material, mode of formation or deposition, and may differ in structure. They certainly differ in their relation to crops, or require different methods of management to produce crops. So far as investigations have gone, they all would seem to have an adequate supply of mineral plant food elements in the soil moisture, yet they appear to have dissimilar chemical powers, especially as regards the reduction of organic bodies, and the products of the same. Considerable progress has been made in selecting new crops and special varieties of crops for some of these soils, and important special industries are already established on soils which a few years ago had low agricultural rank. There seems to be great possibility in this direction in the future.

METHODS OF CONTROL.

Certain plants adapt themselves to certain soil conditions and grow for long periods in an undisturbed soil. This is true generally of forest growths and of most native vegetation. The buffalo grass is fast disappearing with the advent of the plow. The huckleberry bush has not been successfully cultivated until recently, when done through root fungi. Many plants do well in association with certain other plants and will not grow at all in other associations. Practically all of our annual crops, however, require cultivation always before and many of them during most of their periods of growth. This cultivation loosens the soil and puts it in better physical condition for the crop to start in, tends to conserve the moisture, and to keep out weeds, which are generally undesirable by reason of the toxic action of the organic matter thrown off by their roots. But cultivation does more than this. Plowing is essentially a method of fermentation, or, rather, a method to regulate fermentation in the soil; as aromatic principles are developed in certain tobaccos by properly regulating the supply of air by occasionally opening the bulk, so the soil is relieved of many objectionable organic bodies by proper cultivation and the judicious introduction of air. The color of an infertile soil or a raw unproductive subsoil recently turned up to the surface will gradually change and generally darkens with thorough cultivation, and the change in color will indicate to an experienced eye the progress toward more productive conditions.

This is the oldest as it is still the most fundamental method of control of soil fertility. It is a method, furthermore, which requires a high degree of judgment and of skill. Each class of soil requires its own peculiar method, and each change of climatic condition must be considered.

It is often as injurious to plow too much as to plow too little. The time, manner, and condition of the soil are all important factors in regulating cultivation for the maintenance or improvement of fertility. The American farmer has much to learn regarding the best method for the mere handling of his soil. Much of this must come from hard actual experience on the same type of soil for a period of years, but much help may be rendered him through the elucidation of the many at present obscure changes involved in the proper sanitation of the soil.

The second method of controlling the fertility of the soil, and one almost as old as cultivation, is the proper rotation of crops, the importance of which was recognized by the old Latin writers, and clearly recognized by the early English writers.[a]

As soon as we remove the native vegetation which has become adjusted to the soil and introduce new crops forced under cultivation to produce the largest possible yield, the capacity of the soil to reduce

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[a] According to A. B. Griffith, the earliest English work of importance on agriculture was "Ye Boke of Husbandrie," by Sir Anthony Fizherbert, published in 1534. Twenty-eight years after the publication of Fitzherbert's work, Martin Tusser published his famous "Five Hundred Points of Husbandrie" in which he strongly recommends the rotation of crops, thus:

> "Otes, rie or else barlie, and wheat that is gray,
> Brings land out of comfort, and soon to decay;
> One after another, no comfort betweene
> Is crop upon crop, as will quickly be seene,
> Still crop upon crop many farmers do take,
> And reape little profit for greedinesse sake."
>
> A Treatise on Manure, 3rd edition, page 3 (1903).

With all the development of modern agriculture in the taking up of new lands and the enormous increase in the aggregate crop production of the world, it seems apparent from the old writers that agriculture as an art has declined.

According to Dickson, the Romans had a greater variety of crops and exercised considerable more care in adapting them to the different soils than did the English at the time he wrote (1788) or more than we seem to give in this country. Considering Pliny as more particular in his directions as to the adaptation of crops to soil, Dickson gives Pliny's maxims in detail as follows:

"'Such a difference of soil,' as Pliny says, 'points out the necessity of describing the kinds proper for the different crops. This is Cato's opinion, that corn should be sowen on land that is stiff, rich, and in good heart; that raddish, the organic excreta and maintain proper sanitary conditions is often taxed beyond its power to maintain the yield, especially if the same crop is grown year after year. When the crop is changed, a certain crop appearing only once in three or four years, the soil has a longer time to dispose of the waste products. There are, however, two other principles underlying the practice of rotation which, if intelligently used, make it a highly efficient method of control of soil fertility. Some plants are quite indifferent to and are even stimulated or at least benefited by the excreta of other plants, and in thus benefiting they aid in destroying the toxic organic bodies and in purifying the soil.

By growing successive crops of cowpeas or of wheat in small volumes of soil, the bureau has succeeded in making this soil sick for either crop respectively. Pure organic bodies have been isolated from both the soils which are toxic to the plants producing them, but beneficial to the plant which has not caused their accumulation. When wheat is produced on the cowpea soil, therefore, it usually grows better, and after the wheat, cowpeas will grow again better than before. This, in brief, is the principle of rotation modified in details by the nature and previous cropping of the soil and by climatic conditions. The application of empirical rules brought down to us through long experience is very beneficial in maintaining fertility, but much may be expected from the investigation now going on, which will make the practice more effective and more reliable.

The third method of control, namely, the use of manures and commercial fertilizers, has likewise long been practiced, but within recent years the use of commercial fertilizers has grown to enormous proportions in some sections of the country, although used very little or not at all in other sections. The present practice of fertilization is based upon the fallacious doctrine that the soils become exhausted of plant food through continuous cropping and gradually become worn out. If this were so it would have the population of the world eventually dependent upon a few comparatively small deposits of nitrates,

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millett, and panic, should be sowen upon the same kind of land, if moist or wet; that seed should be first sowen in cold and wet, soils, and afterwards in warm; that lupines should be sowen in the red soil, the soil called pulla or sandy soil, if they are not wet; *far* in moisture fields, where the soil is chalky and red; *triticum* [wheat] in dry land, not liable to weeds, nor in a shade; beans in strong soils; *filigo* and *triticum* in open and exposed fields, that receive greatest benefit from the heat of the sun; lentils in uncultivated and red soil where there is not much grass; barley on fallow, and land so rich as to carry a crop every year. Spring sowing should be used in places that cannot conveniently be sowen in autumn, and in soils whose fatness can carry constant crops: This maxim too is exact. These things should be sowen in shallow soil, that do not require much sap, as the *cytifus* and *cicer;* legums are excepted, which are pulled up and not cut in reaping; hence they are called legums, because thus gathered. In fat soil should be sowen such things as require much food, as garden erbs, *triticum, filigo,* flax. So for the same reason, the shallow soil is allotted for barley, because it does not require much food, the richer and stiffer for triticum. In low lying grounds, *far,* rather than *triticum,* should be sowen. In grounds neither very high or low, both *triticum* and barley; hilly ground produces plumper triticum, but not so large a crop: Far and filigo may be appointed to chalky and wet soils.'"

Theophrastus does not enter into particulars, as the Roman authors do, but he declares, in general, that to know how to adapt plants to soils is one of the principal things in agriculture.

The Husbandry of the Ancients; Adam Dickson, Edenburg, 1788; page 187.

phosphates, and potash, and the regulation and conservation of these deposits would be of far more importance than of the coal and iron supply. But we have seen from the statistics given that the soils of the world are not wearing out, but, on the whole, are becoming more productive, and that even the more unproductive soils have ample supplies of mineral plant-food constituents in their soil moisture for better crops than they produce.

While plants may, and undoubtedly do, avail themselves of the mineral plant food elements of the manures and fertilizers, it appears from modern investigations, and is entirely in harmony with experience, that this is not the only benefit derived from their application. Toxic organic bodies which the soil finds difficult to reduce are frequently much more quickly and effectively reduced in the presence of an easily decomposible substance, like fresh cowpea vines or properly fermented manure, while nitrates and other mineral salts help to oxidize or otherwise change to harmless forms the toxic material, thus assisting in the proper sanitation of the soil. Furthermore, certain plants and fertilizers together are much more effective in destroying these toxic bodies than either alone, so that in the rotation for any particular soil there is an order in which the plants should succeed each other, and also when manures and fertilizers are used a most efficient place in the rotation when these should be used, as has already been determined empirically from experience. The effect of cultivation, crop rotation, and fertilizers in improving the physical condition of the soil need not be dwelt upon here.

CONCLUSION.

The fertility of the soil is a great national asset which can not be exhausted. It is not being developed or availed of in all cases as it should be, and will not be until, through investigation, we know more of the peculiarities of certain of our soils, their adaptation to crops, and special methods of control. The soils in different sections of the country are unequally adapted to certain of our staple crops, which permits of specialization, or this difference can undoubtedly be largely minimized through new and improved methods of control if desirable.

In all sections, as in all business and professional work, we have individual cases of failure and success, the cases of failure being generally due to inefficient methods and lack of knowledge, which can be overcome only by better training and education. On the whole, the management of the soils of the world seems to be improving, at least in modern times. This improvement appears to have been greater in Europe, where the population has been denser and the need more pressing than in our own country.

The time has now arrived, when practically all available new lands in this country have been taken up, when improvement must be more rapid than in the past to maintain the integrity of the nation and its commercial supremacy among the nations of the world, and this can best be done by continuing and extending the educational work and the investigations along broad national lines which the administration and the Congress have supported in the past.

Appendix A.

Acreage and yield per acre of cereal crops in European countries.

AUSTRIA.

Year.	Wheat.		Rye.		Oats.		Barley.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1884...	2,735,600	15.5	4,896,900	15.1	4,532,900	26.4	2,655,600	19.8	895,300	18.3
1885...	2,950,600	16.0	4,928,400	15.7	4,519,600	22.9	2,882,300	18.4	908,500	22.2
1886...	2,900,800	15.0	4,970,100	14.9	4,616,300	27.3	2,762,600	19.9	895,900	21.5
1887...	2,876,500	18.0	4,969,700	18.0	4,632,600	25.1	2,798,900	21.7	892,000	18.2
1888...	2,930,000	17.4	4,979,200	16.1	4,630,900	25.1	2,795,800	21.5	897,300	18.6
1889...	2,704,400	13.9	4,876,000	14.2	4,639,300	18.9	2,812,800	16.9	943,700	17.8
1890...	2,835,000	15.1	4,941,600	16.0	4,630,100	24.9	2,757,600	20.6	919,000	21.4
1891...	2,747,900	14.4	4,794,800	14.0	4,679,300	25.7	2,815,800	20.2	923,200	21.2
1892...	2,780,400	17.8	4,865,800	17.0	4,628,700	26.9	2,747,000	23.6	907,800	21.8
1893...	2,766,500	15.4	4,800,800	15.9	4,551,600	21.0	2,777,400	19.4	886,400	17.8
1894...	2,713,000	17.4	4,822,000	17.2	4,643,400	26.0	2,806,900	22.3	806,000	17.0
1895...	2,628,600	15.3	4,477,200	14.5	4,817,600	26.1	2,949,500	20.9	859,400	21.9
1896...	2,615,800	16.0	4,537,800	16.3	4,737,500	23.3	2,911,200	19.4	854,600	20.7
1897...	2,615,100	13.2	4,543,600	13.9	4,724,100	21.5	2,899,200	17.6	829,700	18.0
1898...	2,609,300	18.0	4,513,600	17.7	4,697,900	27.4	2,886,000	22.0	841,500	19.5
1899...	2,649,200	19.0	4,549,800	18.7	4,613,800	30.2	2,939,100	24.9	825,200	17.5
1900...	2,632,400	15.5	4,206,000	13.0	4,692,100	25.2	3,049,500	20.2	827,800	18.7
1901...	2,643,400	16.7	4,474,400	16.9	4,622,400	25.6	2,991,900	22.4	820,700	21.4
1902...	2,614,100	19.0	4,527,300	18.2	4,528,000	27.7	3,005,000	24.6	819,200	16.4
1903...	2,600,600	17.8	4,465,600	18.2	4,530,500	28.3	2,977,600	24.8	824,200	19.5
1904...	2,754,900	19.5	4,760,200	19.3	4,501,500	24.3	2,926,300	22.8	836,200	15.0
1905...	2,782,300	19.6	4,864,600	20.2	4,467,600	27.7	2,935,900	24.0	861,100	20.1
1906...	2,880,400	20.2	4,997,200	19.9	4,529,200	34.1	2,909,900	26.1	836,200	20.7

HUNGARY.

Year.	Wheat.		Rye.		Oats.		Barley.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]
1883...	6,438,300	14.1	2,714,900	14.8	2,453,000	20.9	2,402,600	16.4	4,507,500	19.4
1884...	6,797,800	15.8	2,729,400	15.7	2,457,800	23.2	2,459,600	19.0	4,585,300	19.7
1885...	7,172,100	16.6	3,061,200	14.7	2,841,600	20.9	2,757,100	20.6	5,396,000	22.3
1886...	7,229,800	15.0	3,048,900	13.4	2,876,400	20.8	2,751,100	14.7	5,502,400	17.7
1887...	7,275,200	20.8	3,035,300	17.9	2,857,400	23.0	2,650,100	21.9	5,291,000	15.9
1888...	7,277,500	19.5	2,992,000	15.1	2,846,300	21.2	2,590,100	18.3	5,398,900	20.1
1889...	7,636,800	12.9	2,931,900	13.5	2,757,000	16.7	2,645,800	13.7	5,585,600	20.5
1890...	7,824,300	19.8	2,942,600	18.1	2,692,600	21.1	2,654,200	20.8	5,589,000	18.4
1891...	7,929,700	18.4	2,798,500	14.1	2,722,300	25.2	2,739,300	20.8	5,830,000	27.7
1892...	8,085,800	18.5	2,973,800	16.5	2,714,700	24.3	2,743,500	19.7	6,031,000	21.9
1893...	8,648,500	19.5	3,269,400	17.9	2,625,400	29.2	2,749,600	24.4	5,941,500	25.8
1894...	8,483,900	18.2	2,991,900	19.5	2,664,600	30.1	2,780,600	22.7	5,898,000	14.0
1895...	8,304,800	20.7	2,802,800	16.7	2,593,600	29.6	2,658,400	21.4	6,208,300	26.5
1896...	8,311,200	19.4	2,807,200	18.2	2,546,700	31.4	2,666,200	24.0	6,049,200	24.7
1897...	7,444,800	11.7	2,691,300	13.5	2,450,400	24.3	2,507,300	17.6	5,793,100	20.5
1898...	8,160,100	17.1	2,735,400	16.9	2,587,300	33.1	2,583,600	23.6	6,191,900	23.9
1899...	8,438,000	17.8	2,816,400	17.7	2,626,900	33.3	2,681,400	24.0	6,169,300	21.2
1900...	8,807,000	17.3	2,752,100	15.4	2,672,700	28.5	2,667,700	21.3	6,396,100	22.9
1901...	8,866,300	15.2	2,795,000	15.6	2,674,300	27.6	2,680,800	19.8	6,392,200	23.1
1902...	8,950,300	20.4	2,803,700	18.7	2,679,400	33.3	2,695,700	24.3	6,287,800	19.1
1903...	9,227,000	19.1	2,801,700	18.1	2,776,500	34.1	2,746,800	24.9	6,579,000	24.2
1904...	9,131,300	16.1	2,760,400	16.6	2,703,700	25.0	2,693,800	19.4	5,828,600	12.1
1905...	9,197,700	18.5	2,790,900	19.0	2,759,300	30.5	2,722,400	24.0	6,235,400	18.0
1906...	9,526,600	21.8	2,802,400	19.4	2,815,700	33.4	2,769,800	26.3	6,731,800	28.0

[a] Prior to 1893 Winchester bushels.

Acreage and yield per acre of cereal crops in European countries—Continued.

BELGIUM.

Year.	Wheat.			Rye.		Oats.		Barley.		
	Area.	Average yield.		Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	
		Winter.	Spring.						Winter.	Spring.
	Acres.	*Bush.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Bush.*
1880	681,800	26.6	23.7	686,100	26.5	616,500	48.6	99,300	36.0	31.4
1881	666,000	23.4	19.5	687,000	20.9	616,000	38.7	99,300	35.4	27.9
1882	650,000	25.7	19.9	688,000	26.0	616,000	44.5	99,300	38.6	29.1
1883	635,000	25.0	22.1	689,000	23.9	616,000	41.1	99,300	37.6	31.1
1884	619,000	25.9	22.0	690,000	26.4	616,000	45.4	99,300	42.3	33.8
1885	603,000	27.5	22.7	691,000	26.1	616,000	46.4	99,300	42.7	32.1
1886	587,000	27.0	22.9	692,000	22.4	616,000	52.4	99,400	39.3	35.8
1887	572,000	29.8	....	693,000	27.7	616,000	42.0	99,400	43.9	32.0
1888	556,000	21.9	19.3	694,000	21.7	615,000	50.1	99,400	35.1	32.8
1889	540,000	28.2	21.8	695,000	26.6	615,000	49.2	99,400	40.4	32.9
1890	524,000	28.6	23.2	696,000	28.7	615,000	55.2	99,400	45.4	34.5
1891	509,000	23.0	26.0	696,000	22.4	615,000	59.3	99,400	34.3	38.3
1892	493,000	31.2	25.9	697,000	33.3	615,000	49.2	99,400	44.9	36.9
1893	477,000	27.7	22.7	698,000	28.0	615,000	35.1	99,400	38.8	29.4
1894	461,000	28.4	22.5	699,000	30.5	615,000	50.6	99,400	40.6	32.0
1895	445,700	28.8	25.5	700,200	30.4	614,500	55.8	99,400	43.6	32.0
1896	440,000	30.7	23.7	681,000	32.3	617,000	46.4	99,000	44.6	33.5
1897	434,000	26.9	24.0	662,000	29.5	619,000	54.9	98,000	37.3	31.1
1898	429,000	31.7	22.8	644,000	29.6	621,000	66.8	97,000	42.2	33.9
1899	423,000	26.2	20.4	625,000	26.5	624,000	53.3	96,000	42.3	39.8
1900	417,500	33.0		605,800	32.8	625,800	62.6	95,000	50.1	
1901	409,700	34.5		620,400	34.1	615,800	65.9	94,600	51.3	
1902	415,700	34.9		654,900	34.2	646,200	70.5	93,900	52.9	
1903	355,400	34.7		626,800	34.7	705,800	68.5	79,800	49.2	
1904	393,200	35.1		639,300	34.4	613,300	61.1	98,800	50.7	
1905	402,500	30.8		659,700	32.4	586,500	57.6	94,400	47.9	

DENMARK.

Year.	Wheat.		Rye.		Oats.		Barley.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]
1883	132,900	33.9	670,700	26.4	1,010,500	30.2	769,800	27.1
1884	130,300	36.0	675,400	24.7	1,019,900	30.4	763,100	27.2
1885	127,700	40.1	680,000	26.3	1,027,400	33.1	756,400	27.6
1886	125,100	37.7	684,700	24.2	1,035,800	34.1	749,800	31.0
1887	122,500	43.7	689,300	25.0	1,044,300	30.5	743,100	29.4
1888	119,900	27.4	694,000	23.6	1,052,700	33.7	736,400	30.1
1889	115,600	36.3	697,000	26.0	1,056,900	26.5	730,800	25.5
1890	111,200	33.9	700,100	24.3	1,061,000	35.2	725,100	32.3
1891	106,800	39.1	703,100	27.8	1,065,200	32.3	719,500	31.5
1892	102,500	41.6	706,100	28.9	1,069,300	38.1	713,800	34.6
1893	98,100	39.3	709,100	27.7	1,073,500	25.9	708,200	24.4
1894	93,700	34.8	712,200	23.4	1,077,600	35.6	702,500	30.3
1895	89,400	38.8	715,200	25.7	1,081,700	37.2	696,900	31.3
1896	85,000	43.4	718,200	28.0	1,085,900	35.5	691,200	30.7
1897	....	40.9	....	25.2	....	32.4	....	27.7
1898	....	35.2	....	22.5	....	38.2	....	31.6
1899	....	43.0	....	25.6	....	34.1	....	31.4
1900	....	42.4	....	27.8	....	37.1	....	33.0
1901	32,200	29.2	673,400	24.7	1,069,100	35.0	695,300	32.0
1902		44.7		27.9		38.6		35.5
1903	[b]101,200	44.1	[b]674,300	28.6	[b]1,057,100	39.0	[b]656,600	35.5
1904		42.5		24.5		36.1		34.6
1905		40.3		28.5		30.9		32.2

[a] Winchester bushels.

[b] Area returned by the census of 1901 as intended for the crop named at the time of fall planting; the area actually harvested in 1901, owing to the failure of the wheat crop, differed considerably from these figures.

Acreage and yield per acre of cereal crops in European countries—Continued.

FRANCE.

Year.	Wheat.		Rye.		Oats.		Barley.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1883	16,812,500	17.3	4,249,400	16.4	9,215,700	32.9	2,633,000	22.5	1,556,500	17.7
1884	17,426,300	18.6	4,263,800	17.3	9,135,700	31.2	2,613,100	21.7	1,523,800	18.4
1885	17,190,400	18.2	4,133,900	16.6	9,117,200	30.7	2,361,400	21.7	1,386,000	18.4
1886	17,189,000	17.6	4,038,400	15.8	9,232,000	31.5	2,339,300	22.6	1,357,400	18.7
1887	17,216,900	18.6	4,013,700	16.6	9,192,600	28.2	2,309,000	21.7	1,379,600	21.6
1888	17,243,200	16.0	4,024,900	15.5	9,227,500	29.3	2,208,400	20.8	1,412,100	20.0
1889	17,393,600	17.6	3,952,400	16.5	9,287,500	29.6	2,158,500	21.2	1,379,700	18.9
1890	17,449,800	19.0	3,925,600	17.4	9,342,300	32.6	2,168,400	23.0	1,350,700	17.4
1891	14,220,400	15.2	3,703,000	16.4	10,483,900	32.6	3,022,500	24.7	1,377,900	19.4
1892	17,264,200	18.0	3,809,900	17.6	9,421,700	28.5	2,263,700	21.2	1,381,100	19.5
1893	17,477,800	15.9	3,781,000	17.0	9,495,000	20.7	2,161,300	16.6	1,402,200	18.8
1894	17,276,200	19.9	3,844,300	19.5	9,591,100	30.7	2,200,000	22.6	1,428,900	19.4
1895	17,301,400	19.6	3,789,400	19.0	9,807,400	31.2	2,200,900	22.6	1,444,400	18.3
1896	16,976,900	20.0	3,707,100	18.8	9,677,300	30.6	2,110,000	22.5	1,442,400	21.2
1897	16,268,800	14.9	3,587,300	13.3	9,860,800	25.7	2,119,900	19.6	1,445,500	21.2
1898	17,207,600	21.2	3,644,600	18.4	9,606,200	33.5	2,012,600	24.1	1,388,000	17.2
1899	17,149,500	21.3	3,679,100	18.3	9,734,200	31.6	1,992,300	23.7	1,386,400	18.5
1900	16,961,400	19.2	3,508,300	16.9	9,739,400	29.3	1,871,100	22.6	1,337,300	16.8
1901	16,787,700	18.5	3,489,400	16.7	9,601,700	26.5	1,838,700	21.8	1,351,900	19.9
1902	16,219,200	20.2	3,290,800	13.9	9,469,400	33.8	1,714,700	25.4	1,242,000	20.3
1903	16,009,200	22.7	3,205,500	18.1	9,498,100	36.3	1,722,500	26.2	1,239,500	20.8
1904	16,133,200	18.6	3,144,300	16.8	9,475,500	30.7	1,741,300	22.6	1,224,600	16.2
1905	16,085,800	20.8	3,136,900	18.7	9,420,100	32.5	1,746,200	24.1	1,241,400	19.6
1906	16,103,200	20.4	3,095,100	16.4	9,525,600	31.0	1,752,800	21.6	....	....

GERMANY.

Year.	Wheat.		Rye.		Oats.		Barley.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1883	4,760,300	18.2	14,399,000	15.4	9,323,700	27.6	4,326,500	22.7
1884	4,755,400	19.2	14,447,200	14.9	9,336,400	31.4	4,287,900	23.9
1885	4,742,600	20.2	14,435,500	15.9	9,357,400	32.1	4,305,500	24.2
1886	4,736,100	20.7	14,428,200	16.6	9,406,100	35.6	4,278,600	25.1
1887	4,743,600	21.9	14,436,500	17.4	9,415,300	31.5	4,277,700	23.7
1888	4,777,300	19.5	14,367,300	15.1	9,470,200	33.8	4,257,900	24.4
1889	4,834,400	18.0	14,336,700	14.7	9,604,000	30.1	4,163,700	21.4
1890	4,843,700	21.5	14,382,200	16.1	9,647,000	35.1	4,112,300	25.5
1891	4,658,700	18.4	13,540,500	13.9	10,266,400	35.4	4,464,400	25.9
1892	4,881,900	23.8	14,032,300	19.2	9,853,800	33.2	4,176,300	26.6
1893	5,051,100	24.8	14,856,600	23.7	9,654,300	29.8	4,020,500	27.7
1894	4,893,900	25.0	14,936,400	22.0	9,678,400	46.8	4,023,000	33.1
1895	4,771,200	24.4	14,563,300	20.9	9,955,100	43.2	4,177,500	31.3
1896	4,761,400	26.4	14,782,200	22.7	9,833,900	41.8	4,142,300	30.8
1897	4,746,000	25.3	14,744,100	21.8	9,881,800	39.9	4,116,800	29.1
1898	4,866,200	27.2	14,690,800	24.2	9,875,600	47.1	4,102,200	32.2
1899	4,982,800	28.4	14,507,600	23.5	9,883,500	48.0	(a)	(a)
1900	5,063,500	27.9	14,715,000	22.9	10,187,600	48.0	(a)	(a)
1901	3,907,800	23.5	14,362,100	22.4	10,900,800	44.6	(a)	(a)
1902	4,725,200	30.3	15,208,100	24.6	10,270,400	50.1	(a)	(a)
1903	4,466,300	29.2	14,857,900	26.2	10,601,700	51.2	(a)	(a)
1904	4,738,300	29.5	15,071,500	26.3	10,352,900	46.2	(a)	(a)
1905	4,762,000	28.5	15,186,000	24.9	10,334,000	43.6	(a)	(a)
1906	4,783,900	30.3	15,077,200	25.1	10,431,600	55.7	(a)	(a)

a Not estimated officially.

Acreage and yield per acre of cereal crops in European countries—Continued.

ITALY.

Year.	Wheat.		Rye.		Oats.		Barley.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]
1883[b]	10,956,600	12.1	395,400	13.2	1,079,900	17.0	835,200	13.1	4,675,200	18.0
1884										
1885										
1886										
1887										
1888										
1889										
1890	10,889,900	12.1	348,400	12.7	1,119,400	17.0	820,400	13.4	4,724,600	15.9
1891	11,124,600	12.7	350,900	13.1	1,107,000	18.0	761,100	12.7	4,709,800	15.4
1892	11,193,800	10.3	355,800	11.9	1,112,000	15.5	773,400	10.3	4,702,400	15.3
1893	11,258,100	12.0	358,300	12.6	1,131,700	16.1	798,100	9.9	4,744,400	17.4
1894	11,302,500	10.8	350,900	12.3	1,151,500	14.8	748,700	11.1	4,697,400	12.7
1895	11,349,500	10.4	338,600	11.8	1,171,300	16.4	733,900	10.1	4,835,800	14.6
1896	11,319,800	12.8					761,100	13.2	4,833,400	16.5
1897										
1898										
1899										
1900										
1901	11,910,400	13.8							4,336,700	23.2
1902	11,737,400	11.6							4,200,800	16.9
1903	11,984,500	15.4							4,171,100	21.3
1904	13,336,200	12.6							4,796,800	19.5
1905	13,134,300	12.2							4,845,500	20.2

[a] Winchester bushels. [b] Average, 1879–1883.

NETHERLANDS.

Year.	Wheat.		Rye.		Oats.		Barley.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]
1883	214,100	26.3	493,000	22.0	295,200	38.7	120,000	42.6
1884	219,300	26.9	498,500	21.3	278,300	40.5	116,400	42.0
1885	209,500	30.2	503,800	23.0	283,100	46.1	122,600	44.7
1886	199,300	26.3	503,400	21.3	300,400	48.8	110,100	42.8
1887	210,500	32.7	504,100	27.3	285,300	42.5	111,400	47.0
1888	209,200	25.1	500,200	19.7	281,900	44.5	111,100	38.3
1889	211,000	30.7	501,500	22.6	284,100	47.1	109,700	44.2
1890	209,600	25.9	503,100	22.1	284,300	46.6	104,400	39.8
1891	144,800	24.2	453,500	18.3	377,400	49.1	111,800	40.0
1892	183,400	29.3	495,800	25.1	312,400	48.0	107,700	46.3
1893	175,000	28.4	499,100	24.8	312,200	39.5	103,500	46.1
1894	159,600	26.1	514,700	23.9	327,400	46.1	94,900	38.2
1895	152,900	28.0	519,100	24.7	323,700	48.0	95,700	44.8
1896	153,900	32.8	531,100	25.6	317,400	48.3	97,200	47.0
1897	153,700	27.9	527,400	22.6	331,400	48.7	89,800	41.6
1898	180,600	29.9	530,100	25.8	314,100	52.9	87,000	43.9
1899	177,500	28.7	528,500	24.5	316,800	50.7	87,800	45.2
1900	157,800	29.6	528,900	25.8	324,700	53.3	94,400	48.5
1901	134,600	31.4	532,900	2[illegible].6	334,400	55.3	88,700	43.7
1902	152,400	33.5	539,300	25.9	339,800	56.6	90,100	51.6
1903	137,200	31.0	539,000	25.9	357,100	56.3	78,900	48.5
1904	133,600	33.1	534,000	25.3	357,700	52.0	76,300	47.2
1905	150,700	33.7	541,700	25.4	325,800	49.3	81,700	49.1

[a] Winchester bushels.

Acreage and yield per acre of cereal crops in European countries—Continued.

ROUMANIA.

Year.	Wheat.		Rye.		Oats.		Barley.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]
1886	2,903,700	11.9	570,800	11.2	560,700	17.5	1,371,200	10.6	4,234,400	17.1
1887	2,791,500	17.0	586,600	13.0	582,200	21.2	1,504,600	12.4	4,560,600	10.7
1888	3,104,400	18.6	743,500	19.7	528,600	20.4	1,251,600	18.4	4,283,500	14.7
1889	3,310,900	15.1	424,500	13.5	483,800	13.6	1,263,900	12.5	4,435,800	15.6
1890	3,730,500	13.9	412,900	11.4	441,100	17.2	1,280,200	12.6	4,307,300	14.1
1891	3,811,600	12.7	301,200	12.9	456,900	16.9	1,299,500	17.1	4,184,200	14.3
1892	3,696,900	17.3	328,900	14.1	557,700	19.8	1,384,300	14.9	4,502,500	20.5
1893	3,221,200	18.9	353,400	21.8	622,300	24.8	1,467,600	24.4	4,544,700	16.0
1894	3,441,300	12.7	395,400	14.6	649,100	15.4	1,381,900	12.2	4,367,700	6.8
1895	3,553,400	19.3	537,600	17.2	668,500	15.5	1,365,600	16.4	4,560,300	15.6
1896	3,719,400	19.1	601,500	20.3	696,500	21.1	1,501,700	21.2	4,791,500	13.7
1897	3,941,500	9.2	582,600	11.7	712,000	13.8	1,673,400	12.7	4,583,500	17.4
1898	3,591,900	16.3	477,100	16.0	756,000	23.0	1,618,200	18.3	5,238,800	19.5
1899	4,105,300	6.3	467,900	4.2	766,500	8.2	1,578,200	2.9	4,983,600	5.6
1900	3,927,700	14.4	405,900	14.8	630,800	13.8	1,084,500	13.5	5,029,200	16.9
1901	4,044,000	17.9	522,400	18.3	655,100	25.2	1,244,700	19.5	5,258,400	22.2
1902	3,673,200	20.8	427,000	16.3	793,500	27.6	1,254,700	19.7	5,391,500	12.7
1903	3,967,600	18.6	390,500	18.3	1,054,500	29.8	1,311,900	22.7	5,120,200	15.7
1904	4,254,700	12.6	330,900	6.7	1,052,000	12.0	1,320,100	8.8	5,173,800	3.8
1905	4,838,900	21.4	398,300	33.7	921,000	20.6	1,306,600	21.9	4,882,200	12.1
1906	4,998,500	22.8	454,500	19.6	943,700	27.7	1,380,600	24.3	5,144,500	25.4

[a] Winchester bushels.

RUSSIA.

Year.	Wheat.		Rye.		Oats.		Barley.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1883		7.9		8.5		16.5		10.9		13.1
1884		9.3		10.7		14.3		10.8		11.0
1885	28,879,300	6.2	64,604,600	10.9	34,882,800	11.2	12,441,600	8.1	1,487,800	11.6
1886		5.7		10.3		16.3		10.7		15.3
1887		9.7		11.5		17.7		13.5		8.7
1888		10.3		10.9		15.4		12.7		
1889	30,601,300	6.5	68,936,000	8.3	36,590,800	14.3	14,397,800	8.9		
1890		6.5		9.2		15.7		11.0	(a)	(a)
1891		5.2		6.8		12.4		9.4		
1892	32,440,700	7.1	63,200,300	8.8	34,100,200	13.7	15,485,900	10.9		
1893	32,434,000	10.9	61,961,900	11.1	33,138,000	21.2	15,787,200	18.8	2,258,600	18.0
1894	32,852,200	10.3	63,230,200	12.8	32,846,500	21.4	15,756,200	15.0	2,089,600	9.3
1895	31,894,300	9.2	62,595,300	11.5	33,973,300	19.8	15,808,600	13.3	1,917,600	13.0
1896	34,848,300	8.6	64,238,400	10.9	35,571,600	18.8	16,860,000	12.4	2,184,000	7.9
1897	35,606,400	6.7	62,646,600	9.1	36,206,500	15.1	17,218,800	11.8	2,211,500	20.6
1898	36,007,500	9.3	62,283,400	10.2	35,658,500	15.7	17,589,800	14.5	2,351,600	16.8
1899	38,045,200	8.3	63,405,600	12.7	36,112,400	23.3	17,460,300	10.3	2,406,100	9.4
1900	39,966,900	8.0	65,738,400	12.6	37,399,300	19.9	17,585,400	10.6	2,709,400	9.4
1901	41,921,000	7.6	65,950,300	10.3	37,999,800	13.9	18,128,100	10.4	2,701,100	22.5
1902	42,590,200	10.9	65,871,400	12.3	37,252,400	21.7	18,224,400	15.1	2,860,700	14.1
1903	43,753,200	10.4	66,511,200	12.1	37,590,400	17.3	19,247,000	15.1	2,760,000	14.6
1904	45,635,300	11.4	65,643,600	13.6	37,783,100	26.6	20,069,200	14.5	2,901,300	6.5
1905	48,071,200	9.4	64,689,600	9.7	38,605,700	19.9	20,236,000	13.5	2,870,400	7.9

[a] Statistics corresponding to those of production not available.

Acreage and yield per acre of cereal crops in European countries—Continued.

SERVIA.

Year.	Wheat.		Rye.		Oats.		Barley.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1893	783,500	11.1	147,800	8.9	261,800	12.5	227,600	11.1	1,314,100	13.8
1897	691,300	19.4	91,900	20.7	247,300	39.6	185,200	22.9	1,107,900	30.8
1898	695,900	14.0	111,700	14.2	235,100	27.4	237,200	16.9	1,235,700	22.8
1899	997,900	11.7	146,100	11.4	250,100	19.8	281,400	13.8	1,348,500	19.2
1900	766,100	10.6	87,900	7.7	210,600	12.7	184,900	12.2	1,144,900	16.1
1901	753,200	10.8	93,300	9.5	226,200	14.8	195,000	12.1	1,251,500	15.1
1902	804,600	14.2	98,400	11.0	248,100	16.3	217,900	16.0	1,296,400	14.2
1903	860,100	12.7	105,100	10.4	267,600	16.4	234,900	14.6	1,319,100	14.8
1904	905,400	12.9	111,500	9.2	259,100	12.2	244,700	12.9	1,336,600	7.1
1905	919,600	12.3	117,500	9.4	258,200	13.7	266,300	13.8	1,365,300	15.7
1906	921,400	14.3	120,200	13.0	261,500	17.7	270,200	17.6	1,354,500	20.5

SPAIN.

Year.	Wheat.		Rye.		Barley.		Oats.		Corn.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*[a]	*Acres.*	*Bush.*[b]	*Acres.*	*Bush.*[b]	*Acres.*	*Bush.*[b]	*Acres.*	*Bush.*[b]
1890	8,558,200	8.8	1,709,200	10.5	3,787,100	10.1	....	......	660,300	24.3
1892	8,366,800	10.4	....	......	....	......	....	......	....	......
1893	7,954,200	11.8	....	......	....	......	....	......	....	......
1894	8,252,100	13.3	1,518,100	11.5	2,518,200	23.0	730,100	17.0	826,000	23.1
1895	7,855,900	10.8	1,488,000	11.7	2,429,300	17.7	653,600	13.6	793,800	19.8
1896	7,825,200	10.1	1,674,200	9.2	2,360,600	13.8	683,100	11.5	993,300	18.4
1897	9,532,600	9.7	1,911,800	9.9	3,109,400	14.7	874,800	26.5	1,095,500	18.0
1898	9,543,100	13.1	1,775,800	11.9	3,689,900	19.7	938,000	18.1	1,036,000	14.7
1899	9,052,500	10.8	1,848,800	11.5	3,465,200	15.6	932,000	16.2	1,100,200	22.1
1900	9,559,700	10.5	1,799,000	11.9	3,432,400	16.5	937,200	17.5	1,175,700	22.1
1901	9,172,300	14.9	1,969,000	14.4	3,301,200	24.2	944,200	24.1	1,156,100	22.3
1902	9,150,100	14.6	1,937,900	13.5	3,599,900	22.6	1,111,800	21.0	1,142,700	22.1
1903	8,983,500	14.4	1,930,800	11.7	3,539,800	18.2	1,115,900	20.6	921,000	20.4
1904	9,023,000	10.6	1,889,900	9.1	3,413,900	15.8	1,103,400	16.7	1,072,000	19.8
1905	8,879,200	10.4	1,854,200	14.3	3,336,200	13.8	1,119,400	19.9	1,148,900	27.7

[a] In 1889-1890, bushels of capacity. [b] Prior to 1897, bushels of capacity.

SWEDEN.

Year.	Wheat.		Rye.		Oats.		Barley.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]	*Acres.*	*Bush.*[a]
1890	174,400	23.2	964,500	22.4	1,979,200	32.0	546,200	27.0
1891	175,400	24.7	978,200	22.0	1,992,100	26.4	546,600	23.9
1892	176,300	24.6	987,900	23.3	2,010,800	32.1	550,100	25.2
1893	174,700	22.3	994,600	23.5	2,021,200	27.9	540,300	23.9
1894	175,100	24.9	994,100	19.4	2,022,000	31.4	540,700	26.4
1895	175,800	21.1	997,100	19.2	2,044,600	31.0	542,600	25.7
1896	176,200	26.7	1,007,500	23.0	2,023,000	26.2	538,700	25.2
1897	178,100	26.3	1,012,300	22.7	2,033,100	26.6	542,100	25.2
1898	182,800	25.2	1,014,200	20.4	2,034,700	32.0	545,700	27.2
1899	186,400	24.4	1,012,400	20.0	2,027,500	24.9	545,400	22.9
1900	192,500	28.0	1,015,800	23.3	2,038,200	30.7	537,600	25.7
1901	195,100	21.5	1,013,800	21.5	2,040,100	27.1	537,800	23.7
1902	202,400	23.5	1,017,200	21.9	2,036,100	28.2	531,400	23.1
1903	200,600	27.6	1,013,800	23.0	2,036,300	29.3	528,900	25.7
1904	199,900	25.7	1,016,500	20.4	2,045,900	25.2	526,300	25.6
1905	205,700	26.9	1,014,100	24.1	2,030,800	28.8	514,000	25.0

[a] Winchester bushels.

Acreage and yield per acre of cereal crops in European countries—Continued.

SWITZERLAND.

Year.	Wheat.		Rye.		Oats.		Barley.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1888		19.7		25.7		46.7		27.0
1889	183,000	19.5	77,000	22.2	136,000	43.4	30,000	25.4
1890		24.6		27.8		47.5		28.1
1891		24.2		25.6		48.6		27.5
1892	174,000	25.0	79,000	28.7	139,000	45.6	30,000	27.5
1893		18.8		22.5		30.3		22.0
1894		23.7		24.8		43.2		25.6
1895	165,000	20.9	79,000	21.5	135,000	43.5	27,000	25.0
1896		17.9		19.7		38.8		21.3
1897	160,000	21.5	88,000	23.0	144,000	44.0	27,000	24.2
1898	164,000	24.5	88,000	24.2	141,000	48.0	27,000	26.6
1899		24.7		25.9		47.9		25.8
1900		25.1		25.4		46.8		26.7
1901	164,000	22.0	88,000	24.0	140,000	41.3	27,000	24.4
1902		24.3		24.8		47.1		26.2
1903		25.9		26.6		49.4		28.0
1904	157,000	24.7	92,000	26.9	137,000	48.4	20,000	27.7
1905		22.3		24.9		45.4		25.9

GREAT BRITAIN.

Year.	Wheat.		Barley.		Oats.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.* [a]	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1883	2,613,200	....	2,292,000	....	2,975,400	....
1884	2,677,000	30.9	2,168,800	35.2	2,915,400	38.7
1885	2,478,300	32.3	2,257,300	36.2	2,940,500	38.0
1886	2,285,900	27.7	2,241,200	33.2	3,081,600	39.0
1887	2,317,300	33.1	2,085,200	32.3	3,088,000	35.8
1888	2,564,200	28.9	2,085,600	33.9	2,882,300	38.4
1889	2,449,400	30.8	2,121,500	32.8	2,888,700	40.5
1890	2,386,300	31.7	2,111,200	36.1	2,903,000	42.7
1891	2,307,300	32.2	2,112,800	35.2	2,899,100	40.0
1892	2,219,800	27.2	2,036,800	35.7	2,997,500	40.0
1893	1,897,500	26.8	2,075,100	29.6	3,171,800	36.7
1894	1,928,000	31.7	2,095,800	35.6	3,253,400	42.9
1895	1,417,500	27.1	2,166,300	32.7	3,296,100	38.2
1896	1,694,000	34.7	2,104,800	34.7	3,095,500	38.0
1897	1,889,200	30.0	2,035,800	33.9	3,036,100	39.7
1898	2,102,200	35.8	1,903,700	36.9	2,917,800	42.0
1899	2,001,000	33.8	1,982,100	35.2	2,959,800	40.0
1900	1,845,000	29.4	1,990,300	32.3	3,026,100	39.1
1901	1,700,800	31.8	1,972,400	32.0	2,996,900	37.9
1902	1,726,400	33.9	1,909,400	35.9	3,057,000	44.0
1903	1,581,500	31.1	1,858,500	33.0	3,140,200	41.0
1904	1,375,200	27.7	1,840,700	32.1	3,252,900	40.4
1905	1,796,800	33.8	1,713,700	35.0	3,051,400	39.4
1906	1,755,600	34.7	1,751,200	35.7	3,043,000	41.8

a Winchester bushels.

Acreage and yield per acre of cereal crops in European countries—Continued

IRELAND.

Year.	Wheat.		Barley.		Oats.		Rye.	
	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.	Area.	Average yield.
	Acres.	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*	*Acres.*	*Bush.*
1883	94,700	25.5	183,600	35.9	1,381,900	47.7	7,200	22.9
1884	67,900	27.3	167,400	37.4	1,348,400	47.0	7,100	22.2
1885	71,000	28.8	179,500	37.6	1,328,900	47.8	8,400	25.4
1886	69,500	27.0	181,900	35.6	1,322,000	48.7	10,600	23.2
1887	67,200	28.3	162,400	29.8	1,315,100	40.3	10,800	21.6
1888	99,000	25.8	171,300	36.9	1,280,900	48.2	13,900	26.8
1889	89,700	29.9	186,300	40.7	1,239,000	49.8	15,800	25.8
1890	92,300	28.6	182,400	39.2	1,221,000	51.0	14,600	23.2
1891	80,900	32.3	178,300	43.4	1,215,400	54.2	13,400	27.1
1892	75,400	29.4	175,600	38.3	1,226,200	51.6	13,100	25.1
1893	55,000	30.3	169,000	38.3	1,248,300	54.4	13,500	26.5
1894	49,300	31.0	164,800	39.9	1,254,800	53.8	11,900	25.5
1895	36,500	30.4	171,800	38.7	1,216,400	52.4	11,500	26.7
1896	38,000	31.4	173,400	42.3	1,193,600	49.9	13,700	25.5
1897	47,200	28.7	170,700	35.4	1,175,100	48.4	13,100	21.7
1898	52,800	35.2	158,200	44.0	1,165,400	56.1	12,400	25.5
1899	51,900	33.4	169,700	41.8	1,135,500	55.2	12,100	25.7
1900	53,800	31.3	174,200	37.3	1,105,000	55.5	11,400	25.7
1901	42,900	34.2	161,700	42.1	1,099,300	56.6	11,000	27.3
1902	44,200	36.2	167,900	49.3	1,082,100	60.6	9,600	28.1
1903	37,600	31.3	158,800	38.3	1,097,500	53.6	10,000	26.9
1904	30,800	33.7	158,100	34.7	1,078,800	55.8	9,400	26.0
1905	37,900	37.8	154,600	46.4	1,066,800	56.9	10,200	27.0
1906	43,900	34.8	176,500	40.9	1,076,300	58.3	10,300	27.6

APPENDIX B.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, with respect to potash, phosphoric acid, lime, and magnesia.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
California[a]	1	0.555	0.230	0.955	1.052
Illinois	3	.161	.066	.210	.247
	5	.525	.106	.610	.643
Kansas	7	.643	.089	.575	.510
Indiana	9	.496	.166	.465	.450
Massachusetts	12	.153	.144	.525	.558
Michigan	14	.118	.064	.490	.275
Missouri	16	.272	.121	.405	.550
Montana	18	.731	.185	.870	.907
New York	19	.321	.189	.250	.518
South Dakota	22	.390	.153	.665	.628
Texas	25	.095	.032	.175	.162
Wisconsin	27	.230	.125	.405	.412
Illinois	35	.580	.085	.520	.866
Iowa	39	.337	.137	.790	.585
New York	51	.351	.156	.140	.585
California	63	.594	.163	1.535	1.726
	65	.508	.117	.900	1.542
Illinois	69	.156	.070	.230	.218
	70	.479	.185	1.455	.989
Indiana	73	.384	.105	.370	.450
Iowa	74	.365	.093	1.185	.662
Kansas	76	.766	.128	.675	.615
Michigan	80	.134	.066	.405	.281
Montana	84	.747	.176	.970	1.105
New York	85	.246	.202	.125	.549
South Dakota	87	.365	.147	.710	.585
Texas	89	.053	.035	.150	.104
Wisconsin	90	.295	.163	.535	.457

[a] This and following samples, to and including number 90, analyzed by Moore, Jour. Am. Chem. Soc. 24, 85 (1902).

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Washington:[a]		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Yakima County	17	1.07	0.13	2.00	1.34
Kittitas County	37	.70	.18	2.08	1.47
Oregon,[a] Morrow County	79	.89	.18	1.37	1.08
Alabama[b]	....	.15	.017	.051	.01
Butler County	1129	.182	.029	.275	.293
Talladega County	1131	.908	.150	.289	.633
Pike County	1133	.149	.032	.039	.062
Arizona:[c]					
Glendale	3	.955	.244	2.213	2.535
	4	.528	.148	3.028	1.991
	5	.777	.220	2.721	2.441
	6	.472	.140	2.883	2.025
Granite Mountains	11	.671	.059	2.068	1.391
Orangewood	10	.630	.112	2.453	1.668
Tempe	17	.783	.080	1.336	1.317
	14	.593	.058	1.354	1.188
Glendale	1	1.025	.053	.981	1.764
	2	.563	.122	1.282	1.356
Orangewood	9	.860	.106	1.284	1.713
	7	.818	.207	2.703	2.326
Mesa	19	1.959	.227	1.240	2.102
	8	.970	.210	2.419	2.541
Tempe	16	1.094	.179	5.711	3.086
	18	1.045	.147	2.611	2.013
	15	.683	.149	3.513	1.466
Glendale	12	.777	.053	4.205	1.564
	13	.686	.045	2.854	1.447
Casa Grande	20	.534	.031	.579	.775
California, Needles[d]	21	.928	.185	6.427	....
California:[e]					
Amador County	1291	.64	.05	.20	.18
	1294	.26	.07	.17	.16
	1115	.53	.05	.50	.30
	1113	1.48	.05	.60	2.21
Butte County	1139	.26	.07	6.10	1.23
Shasta County	1028	.273	.041	.113	.306
Merced County	1192	.26	.03	.49	.33
Fresno County	1061	.418	.028	1.417	1.955
	1065	.29	.02	1.02	.63
	1055	.82	.07	1.14	1.58
	1189	1.32	.06	.99	1.54
	1190	.67	.16	1.31	1.74
	1191	1.01	.08	1.10	1.28
Alameda County	1029	.28	.70	8.21	.43
Santa Clara County	999	.31	.11	1.39	16.97
Napa County	1075	1.48	.08	.30	1.43
	1077	.67	.08	2.49	10.77
Sacramento County	880	.65	.08	.71	1.71
Contra Costa County	123	.24	.06	.66	.34
San Bernardino County	809	.79	.11	1.51	1.24
	812	.97	.05	1.65	1.68
	1406	.87	.14	1.57	1.33
	1536	.73	.07	1.58	1.85
	1537	.69	.03	1.71	1.78
	1248	.74	.09	1.11	1.40
	1251	1.17	.11	1.19	1.29
	1246	.68	.12	1.15	1.30
	1253	1.17	.11	.96	1.27
San Diego County	1238	.64	.06	1.06	....
	1092	1.42	.35	2.20	2.09
Arizona:					
Near Yuma	506	1.18	.13	8.67	2.97
Gila River Valley	1195	.66	.23	6.26	.66
California:[e]					
Sutter County	1645	.74	.24	2.06	2.13
Tehama County	1636	.50	.26	.81	1.14
Sacramento County	1698	.49	.20	1.45	.94
	1699	.62	.11	1.55	.94

[a] Hilgard, Weather Bureau Bul. No. 3, p. 18 (1892).
[b] Bul. 3, Alabama Agr. Expt. Sta., No. 3, p. 13.
[c] Bul. 28, Arizona Agr. Expt. Sta., pp. 77–92 (1898).
[d] Ann. Rep. Cal. Agr. Expt. Sta., 1890, pp. 23–50.
[e] Results for this and the following samples to and inclusive of 2411 from Ann. Rep. Cal. Agr. Expt. Sta., 1899–1901, 1893–4, 1894–5, 1895–1907; Nos. 2324 to 2430, inclusive, from Bul. 147, Cal. Agr. Ept. Sta. (1903); No. 2430 from Bul. 140, Cal. Agr. Expt. Sta. (1902).

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
California—Continued:					
Kern County	1466	1.04	0.22	1.29	1.24
Sonoma County	1647	.99	.16	.90	1.97
Napa County	1655	1.28	.09	.54	.91
Alameda County	1679	.73	.19	1.15	1.08
San Luis Obispo County	1693	.51	.29	1.04	.34
San Benito County	1704	.45	.16	1.16	2.09
Ventura County	1714	.47	.21	.07	.57
Riverside County	1758	1.37	.23	4.23	3.80
	1759	.84	.12	2.19	2.32
	1760	1.16	.28	8.00	5.69
	1761	1.01	.22	13.94	6.16
Orange County	1016	.80	.08	2.04	1.92
Tulare County	1159	1.20	.10	1.86	1.81
	1157	1.31	.14	1.70	1.96
	1163	1.24	.09	3.06	2.71
East Highlands	....	.98	.13	.96	1.42
Riverside	....	.87	.14	1.57	1.33
Corona	....	1.17	.11	1.19	1.29
Wheatland	2403	.42	.20	.72	1.45
	2405	.42	.14	.97	1.83
	2408	.65	.21	.83	1.50
	2411	.23	.09	.25	.29
Salton Basin	2324	.76	.23	4.35	1.24
	2325	.74	.22	3.75	1.68
Berkeley	2430	.33	.07	.76	.76
Colorado:[a]					
Arkansas Valley	1	.23	.23	2.80	.97
	2	.27	.22	1.28	.97
	3	.59	.21	3.69	1.61
Yuma	4	.39	.14	1.46	.69
Fort Collins	5	.56	.16	3.58	.73
	6	.62	.15	2.17	1.00
	7	.41	.21	.70	.85
	8	.66	.29	.91	.69
San Luis	9	.41	.23	.67	.54
	10	.27	.23	.81	.56
	11	.14	.14	.68	.67
Fort Collins	....	.41	.21	.70	.85
Florida:[b]					
Lake City	D	....	.02	.03	.02
	E	....	.70	.34	.13
	....	....	.07	.06	.03
	....	....	.02	.03	.05
Auburndale	16	....	.01	.10	.03
	....	....	.005	.007	.00
	....	....	.005	.008	.003
Tobacco soil	....	.018	.053	.130	.008
Tobacco soil (Cuban)	....	.160	1.60	7.60	.17
Pineapple soil	....	.006	.012	.000	.009
Orange soil	....	.014	.018	.034	.022
Cotton soil	....	.010	.032	Trace.	.020
Indiana:[c]					
Newton County	....	.47	.17	....	....
	....	.23	.22	....	....
Hendricks County	....	.680	.284	....	....
	....	.181	.222	....	....
Fountain County	....	.428	.123	....	....
	....	.281	.154	....	....
Delaware County	....	.32	1.01	....	....
	....	.35	.46	....	....
	....	.21	.16	....	....
	....	.22	.36	....	....
Kentucky:[d]					
Hodgenville	2003	.090	.172	.080	....
Lagrange	2004	.190	.182	.190	....
Beard	2130	.532	.096	.198	....
	2131	.515	.080	.175	....
Newport	2276	Trace.	.592	....	....
Lexington	2501	.510	.537	.605	.503
	2502	.480	.445	.425	.393

[a] Buls. 9 and 10, Colo. Agr. Expt. Sta. (1890).
[b] Bul. 5, Fla. Agr. Expt. Sta. (1899); Bul. 6 (1889); Bul. 19 (1893); Bul. 87 (1906).
[c] Bul. 95, Ind. Agr. Expt. Sta., pp. 25–29 (1903).
[d] This and following samples to and including No. 8599, Rep. Ky. Agr. Expt. Sta., 1892, 1893, 1894, 1899, 1901, 1902, 1903; Nos. 14398 to 14604, Bul. 126, Ky. Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Kentucky—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Casky	2600	0.310	0.117		
Meade	6039	.178	.030		
	6040	.249	.040		
	6041	.204	.055		
	6943	.214	.060		
	6944	.308	.039		
Shelbyville	7716	.096	.27	0.26	
Scottsville, Allen County	7720	.120	.015	.120	
Lincoln County	7885	.169	.064		
Logan County	8457	.397	.073		
Lewis County	8599	.251	.038		
Boone County	8810	.223	.090		
	8847	.234	.090		
Marshall County	8856	.308	.038		
	8857	.411	.042		
Kenton County	8897	.357	.094		
Breckenridge County	9541	.26	.07		
	9802	.160	.158		
Casey County	9800	.159	.069		
Fayette County	10249	.318	.475	.520	0.320
Henry County	9798	.264	.123		
Hopkins County	9623	.145	.052		
	9624	.165	.072		
Livingston County	10493	.471	.263		
	10494	.505	.230		
	10495	.475	.170		
	10496	.214	.030		
Pulaski County	9766	.141	.030		
Grayson County	11067	.148	.063		
Meade and Hardin counties	11068	.134	.074		
Henderson County	11188	.273	.077		
Hickman County	11170	.224	.080		
	11171	.440	.118		
Hopkins County	11174	.102	.064		
Lincoln County	10735	.160	.041		
Logan County	11119	.220	.155		
Boone County	14398	.206	.076		
Boyd County	14401	.130	.064		
Casey County	14407	.542	.058		
Clark County	14411	.710	.377	.500	.480
	14412	.732	.455	.600	.500
	14610	.549	1.335	.725	.280
	14613	.646	1.755	1.100	.240
	14654	.375	.855	.712	.400
	14618	.638	1.695	1.175	.320
	14648	.455	.485	.739	.420
	14616	.407	.710	.350	.200
	14650	.407	.512	.607	.520
	14652	.401	.755	.739	.480
Fayette County	14408	.360	.132		
	14409	.576	.182		
	14498	.417	.524		
	14577	.582	.302		
	14490	.405	.450	.400	.400
	14491	.400	.444	.475	.520
	14492	.380	.390	.400	.400
	14493	.410	.562	.600	.480
	14494	.407	.590	.650	.480
	14495	.452	.770	.725	.420
	14482	.435	.490		
	14483	.437	.474		
	14484	.337	.392	.300	.220
	14485	.347	.322	.350	.340
Henry County	14399	.278	.356		
	14477	.300	.274		
Knox County	14633	.125	.042		
Muhlenberg County	14636	.483	.120		
Ohio County	14410	.262	.040	.200	.300
Pendleton County	14400	.202	.096		
Rockcastle County	14480	.180	.038		
	14499	.350	.054		
Warren County	14509	.430	.070		
	14592	.188	.046		
	14593	.256	.055		
	14594	.307	.050		
	14595	.280	.025		

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Kentucky—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Woodford County	14513	0.340	0.428	....	....
	14606	.472	.625	....	....
	14604	.548	1.385	1.725	0.240
Louisiana [a]	1a	.100	.064	.170	.114
	2a	.120	.112	.060	.021
Maine,[b] Scarboro	....	.24	.29	....	....
Maryland: [c]					
Washington County	133	.55	.50	.56	....
	134	.35	.32	.56	....
	463	.45	.24	.31	....
Virginia,[c] Martinsburg	465	.43	.28	.12	....
Maryland,[c] Washington County	466	.22	.20	.56	....
	467	.32	.19	.31	....
Michigan: [d]					
Lenawee County	1	1.84	.40	1.98	1.43
	2	2.05	.41	2.10	1.59
Washtenaw County	3	1.18	.40	1.28	.86
Cass County	4	1.18	.44	2.02	.66
	5	1.10	.33	1.38	.56
Shiwassee County	6	1.85	.49	1.64	1.23
Agricultural College	7	.85	.30	1.22	.59
	8	2.12	.41	1.28	.89
	9	1.97	.31	1.46	.43
Van Buren County	10	.83	.13	.51	.46
Lake County	11	.90	.23	.62	.28
Mason County	12	.65	.22	.66	.12
	13	2.10	.30	1.00	.89
Osceola County	14	1.19	.29	.80	.64
Mecosta County	15	1.96	.44	.94	.48
	16	1.80	.33	1.14	.49
Wexford County	17	.83	.15	.65	.24
Missaukee County	18	1.95	.28	1.15	.98
Grand Traverse	19	.89	.13	.37	.41
Benzie County	20	1.10	.21	.55	.27
Antrim County	21	.98	.18	.95	.36
Grayling	22	.20	.05	.20	.12
	23	.33	.04	.24	.17
	24	.30	.01	.32	.15
Kalamazoo	26	.34	.88	6.09	.81
Grand Haven	27	.20	.69	5.02	.62
Luce County	28	.42	.46	4.18	.75
Isabella County	29	.86	.19	.87	.27
Midland County	30	1.85	.49	1.64	1.23
Clare County	31	.54	.15	.36	.16
	32	.90	.36	.99	.73
Lake County	33	.73	.14	.35	.30
Gratiot County	34	.92	.14	.68	.30
Bay County	35	1.18	.38	1.18	.46
Montcalm County	36	1.13	.20	.82	.31
Otsego County	37	.61	.14	.40	.13
Iosco County	38	1.10	.16	.93	.36
Minnesota: [e]					
Red Wing	285	.15	.10	.47	.21
Gilford	265	.33	.10	.56	.38
Good Thunder	269	.46	.09	.60	.16
Langdon	290	.17	.15	.48	.20
Eden Prairie	304	.11	.22	.74	.41
Faribault County	300	.30	.19	.70	.40
Grant County	266	.21	.10	1.00	.42
McLeod County	234	.25	.20	.23	.36
Martin County	261	.31	.15	.58	.19
Meeker County	302	.25	.18	2.48	.97
Goodhue County	257	.16	.30	.76	.81
Warren	203	.54	.38	2.44	1.85
	298	.50	.31	2.40	1.91
Crookston	202	.60	.29	2.55	.67
	236	.54	.24	2.49	.62
	272	.90	.13	1.07	.84
Twin Valley	306	.18	.13	.48	.25
Gossen	308	.30	.19	1.20	.80

[a] Bul. 22, La. Agr. Expt. Sta., p. 739.
[b] Ann. Rep. Me. Agr. Expt. Sta., 1894.
[c] Ann. Rept. Md. Agr. Expt. Sta., 1889, p. 86.
[d] Bul. 99, Mich. Agr. Expt. Sta., 1893, pp. 6–15.
[e] This and the following samples to and including No. 257 from Ann. Rept. Minn. Agr. Expt. Sta., 1893; Nos. 203 to 329, Bul. 30, 41, and 65, Minn. Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Minnesota—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moorhead	275	0.73	0.20	1.29	0.39
	224	.45	.35	.69	.38
	312	.28	.30	.65	.77
	222	.18	.21	.61	.65
	259	.34	.21	1.00	.25
	249	.32	.26	1.53	.65
	298	.32	.25	.92	.24
Worthington	326	.36	.65	1.06	.82
Benson	214	.46	.27	13.56	2.57
Fergus Falls	208	.17	.32	.54	.33
Alexandria	210	.44	.31	1.26	.35
Wadena	245	.28	.20	.60	.60
Park Rapids	230	.26	.15	.61	.18
Henning	292	.19	.36	.63	.13
Fair Haven	273	.20	.21	.77	.25
Mille Lacs	216	.14	.22	.38	.29
Pine	236	.08	.04	.11	.12
Hinckley	228	.18	.12	.76	.25
New Duluth	232	.27	.33	.32	.51
Wyanette	288	.08	.10	.21	.13
Saint Cloud	212	.85	.19	.26	.10
Duluth	264	.25	.45	.51	.12
Farmington	277	.20	.20	.46	.18
	279	.19	.20	.48	.27
Rolling Stone	239	.30	.23	.41	.39
Faribault	280	.23	.21	.54	.30
Owatonna	283	.23	.13	.48	.18
Experiment station	242	.30	.23	.51	.26
Austin	218	.32	.38	.48	.45
Wells	220	.36	.25	1.10	.99
Mankato	294	.19	.30	.53	.11
Polk County	464	.84	.29	1.10	.59
Norman County	320	.43	.30	5.05	2.57
Polk County	317	.34	.27	.71	.63
Wilkin County	448	.37	.20	.89	.53
	446	.27	.22	1.36	.30
Lincoln County	428	.29	.15	.88	.73
Chippewa County	442	.38	.26	.56	.74
	444	.46	.26	1.05	.70
Kandiyohi County	414	.25	.21	.70	.43
Grant County	266	.21	.10	1.00	.42
Martin County	261	.31	.25	.58	.19
Meeker County	202	.25	.18	2.48	.97
Wright County	432	.13	.23	.69	.42
McLeod County	462	.17	.20	.95	.66
Hennepin County	430	.30	.38	.51	.50
	451	.29	.32	.92	.45
Ramsey County	374	.28	.19	.52	.21
Wadena County	420	.30	.45	.94	.51
Becker County	422	.25	.47	.88	.55
Todd County	418	.17	.31	.56	.26
	424	.16	.13	.47	.24
Ottertail County	456	.15	.16	.78	.17
Cass County	414	.27	.20	.28	.11
Dakota County	436	.32	.06	.31	.38
	434	.30	.28	.58	.40
Wabasha County	468	.27	.26	.67	.54
Goodhue County	285	.22	.10	.40	.17
	257	.26	.30	.76	.81
Rice County	489	.32	.16	.51	......
Houston County	483	.34	.32	.42	.47
Freeborn County	470	.27	.26	.60	.46
Fillmore County	487	.41	.12	.46	.66
Faribault County	300	.30	.19	.70	.40
Olmsted County	485	.61	.24	.30	.77
Blue Earth County	269	.46	.19	.60	.16
Washington County	440	.26	.19	.29	.43
	314	.17	.20	.28	.11
Chisago County	499	.20	.20	......	......
Pine County	426	.18	.13	.33	.29
	228	.25	.12	.76	.25
Carlton County	474	.12	2.61	.20	.39
Chisago County	497	.34	.10	.22	......
	495	.31	.11	.17	......
Pine County	501	.38	.22	.47	......

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Minnesota—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dakota County	563	0.42	0.19	0.41	0.40
	557	.29	.16	.33	.34
	535	.44	.16	.46	.25
	513	.23	.36	.58	.69
Goodhue County	553	.40	.17	.64	.70
	521	.48	.18	.69	.61
	527	.51	.20	.70	.76
	616	.50	.20	.56	.23
	555	.44	.14	.49	.64
	577	.38	.16	.50	.51
	573	.37	.13	.59	.61
	572	.55	.17	.48	.51
Hennepin County	542	.43	.23	.42	.41
Wabasha County	515	.20	.31	.64	.72
	618	.44	.22	.41	.10
	503	.20	.38	.49	.44
Winona County	596	.38	.15	.43	.51
	597	.45	.26	.52	.45
	598	.44	.18	1.69	1.17
Freeborn County	592	.54	.27	.61	.53
	594	.46	.25	.67	....
	567	.42	.18	.52	.29
	584	....	.29	2.36	.77
	586	.29	.22	1.94	6.12
	519	.63	.11	.40	.57
Mower County	533	.37	.19	.49	.33
Fillmore County	633	.49	.32	3.22	.20
Waseca County	505	.21	.48	.53	.44
	465	.57	.22	.70	.29
Martin County	561	.57	.11	.93	.76
Watonwan County	531	.49	.15	.81	.54
	606	.45	.19	.40	.17
	607	.36	.19	.77	.37
	608	.46	.24	2.55	.20
Nicollet County	523	.52	.20	.62	.73
Sibley County	559	.43	.16	.63	.45
Renville County	511	.42	.32	.97	.60
Lyon County	599	.56	.24	.57	.67
Lac qui Parle County	568a	.50	.19	14.00	1.33
	502	.54	.29	1.65	.67
Big Stone County	537	.35	.20	.68	.73
Kandiyohi County	624	.58	.20	1.42	.38
	588	.34	.14	.72	.60
	590	.50	.18	1.31	.74
	620	.62	.21	.87	.11
Swift County	609	.33	.24	.58	.33
	525	.39	.16	.99	.27
Polk County	551	.57	.19	.74	.68
Ottertail County	517	.51	.16	.97	.61
	632	.44	.14	.71	.25
Becker County	571	.73	.16	.89	.76
Norman County	612	.66	.34	4.60	2.00
	613	.60	.32	8.67	1.69
	614	.73	.16	1.10	.60
Kittson County	569	1.16	.19	1.25	.58
Hubbard County	611	.20	.04	.48	.25
Isanti County	509	.10	.23	.38	.29
Sherburne County	579	.18	.11	.28	.21
Morrison County	575	.23	.14	.44	.34
Itasca County	540	.15	.11	.42	.30
	544	.55	.07	.74	1.04
	548	.18	.13	.19	.22
Beltrami County	666	.35	.14	.76	.36
Stearns County	600	.27	.10	.51	.24
	602	.37	.09	.27	.13
	630	.43	.21	.70	.37
Chisago County	529	.36	.30	1.22	.41
Mississippi: [a]					
Ocean Springs	692	.050	.027	.160	.072
	694	.056	.015	.230	.064
	695	.080	.004	.200	.028
Sentobia	1,489	....	.270	1.560	.460
McNeil Experiment Station	....	.142	.023	.220	.162
		.210	.017	.170	.140

[a] This and following samples to and including 1489, Ann. Rpt. Miss. Agr. Expt. Sta., 1890; samples from McNeil Expt. Sta., Bul. 99, Miss. Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
North Dakota:[a]		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Red River Valley (average 21 samples)		0.54	0.19	4.16	0.81
James River Valley (average 5 samples)		.48	.27	1.07	.57
Cheyenne River Valley (average 2 samples)		.54	.17	14.67	.93
Mouse River Valley (average 4 samples)		.34	.18	2.19	.51
Devils Lake region (average 10 samples)		.57	.12	6.08	.61
Turtle Mountains (average 8 samples)		.55	.14	.77	.47
Wells County (average 2 samples)		.45	.19	.41	.28
Rolette County (average 7 samples)		.45	.25	.96	.14
West Missouri (average 2 samples)		.35	.19	.32	.43
Station farm	422	.45	.27	1.25	Trace.
	423	.44	.33	.83	Trace.
	424	.60	.38	.80	Trace.
	425	.73	.40	.86	Trace.
	426	.54	.38	1.01	Trace.
	427	.63	.39	.85	Trace.
	428	.50	.38	1.05	Trace.
Mayville, Old		.22	.37	2.10	.08
Mayville, New		.18	.31	2.00	.07
Station Plats	A	.77	.21	1.47	.72
	B	.61	.20	.65	.23
	1	.79	.27	1.08	.34
	2	.82	.29	1.39	.50
	24	.78	.38	1.07	.44
	25	.96	.39	1.19	.68
Oregon:[b]					
Lincoln County	1A	1.03	.06	.23	1.13
	1B	.10	.27	1.40	1.65
Washington County	1C	.03	.03	.34	1.71
	1D	.16	.32	.63	1.18
Wasco County	1E	.00	.02	.65	1.41
Washington County	1F	.12	.00	.75	7.13
	1G	.28	.34	1.35	.90
	1H	.26	.34	.76	.71
Benton County	1I	.11	.01	1.60	1.78
	1J	.47	.05	1.60	1.08
Polk County	1K	.24	3.26	.60	.55
Washington County	1L	.11	.30	1.47	1.27
Lincoln County	1M	.12	.08	.53	.82
Washington County	1N	.19	.06	.43	1.54
Lincoln County	1O	.26	.21	.31	.52
	1P	.28	.33	.30	.40
	1Q	.33	.12	.27	.25
	1S	.16	.08	.42	.98
	1T	.22	.12	.45	2.04
	1U	.33	.11	.27	.52
Lane County	1V	.09	.16	.60	.27
Linn County	1W	.15	.11	3.51	.21
Douglas County	1X	.44	.16	2.05	.42
Crook County	1Y	.83	.08	1.21	1.11
Union County	1Z	.81	.07	.76	.24
Washington County		.18	.23	1.49	.26
Marion County	2A	.66	.13	.97	.09
	2B	.04	.28	.10	.91
Baker County	406	.51	.14	1.13	1.93
	407	.03	.02	.94	.01
Polk County	409	.02	.02	2.01	.02
	424	.39	.47	.75	.87
Washington County	425	.02	.04	.82	.85
Marion County	426	.47	.63	.40	.96
Columhia County	447	.29	.31	.59	.80
Lincoln County	448	.11	.40	.46	.63
Washington County	449	.11	.25	.50	.00
	2N	.51	.54	.49	.71
	623	.17	.12	1.13	.38
	624	.23	.21	.64	1.45
Lane County	454	.19	.13	.65	.46
Polk County	625	.47	.22	.56	.79
Umatilla County	408	.23	.25	1.86	.09
Renton County	597	.33	.25	.89	.80
Jackson County	612	.33	.14	2.32	.83
	613	.21	.14	5.15	.72

[a] This and the following samples to and including Mayville, N. Dak., from Bul. 35, N. Dak. Agr. Expt. Sta. (1899); samples A to 25, Ann. Rpt. N. Dak. Agr. Expt. Sta., 1902.

[b] Samples 1A to 627, Bul. 50, Oreg. Agr. Expt. Sta. (1898) samples 2382 to 2542, Ann. Rpt. Oreg. Agr. Expt. Sta. (1903).

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Oregon—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Josephine County	615	0.19	0.21	2.49	0.46
	615½	.27	.23	3.49	.43
Linn County	643	.39	.40	.50	.71
Wasco County	644	.12	.28	1.41	1.10
Marion County	626	.12	.29	.95	.62
	622	.46	.07	Trace.	.05
Multnomah County	629	.25	.40	1.27	1.23
Josephine County	616	1.85	.06	3.11	3.36
Douglas County	618	1.27	.28	.13	.08
Wasco County	762	.31	.22	.82	.15
	763	.20	.25	.38	.24
	764	.41	.82	.84	.24
Coos County	765	.20	.11	.52	.16
	766	.29	.38	.41	.60
Benton County	410	.06	.03	.66	.00
	411	.21	.34	.46	.05
Marion County	628	.48	.19	.32	.50
	628½	.52	.22	.34	.33
Yamhill County	768	.26	.23	.63	.63
	769	.38	.76	.43	.53
Marion County	619	.50	.35	.35	.22
	619½	.62	.30	.00	.28
Josephine County	617	.31	.05	.28	.35
	622	.30	.00	.72	.33
Marion County	627	.38	Trace.	.71	.91
	2382	....	.88	....	....
	2383	....	.15	....	....
	2407	.12	.23	.36	....
	2410	.15	.17	.24	....
	2425	.06	.11	14.36	....
	2448	.19	.21	.40	....
	2449	.18	.24	.33	....
	2450	.22	.20	.41	....
	2540	.26	.25	1.50	.64
	2541	.26	.39	5.63	2.19
	2542	.37	.36	1.25	.86
Washington [a]	5	.635	.142	1.081	.727
	11	.331	Trace.	1.512	1.527
	16	.530	.139	1.180	.733
	17	.432	.100	1.212	.788
	19	.202	.038	.655	Trace.
	20	.007	.054	.769	.426
	21	.136	.313	.379	.036
	22	.112	.079	1.112	.031
	25	.590	.353	.362	.281
	26	.233	.198	.397	.031
	27	.015	.140	.109	.022
	28	.277	.300	.082	.065
	29	.448	.345	.781	.122
	31	.650	.543	.431	.033
	32	.012	.311	.130	.033
	33	.047	.399	.398	.018
	34	.120	.172	.675	.116
	39	.274	.166	.979	.015
	40	.058	.159	1.758	.647
	41	.442	.191	.930	.362
Spokane County	30	.436	.265	.604	.430
	114	.374	.096	.644	.297
	119	.663	.070	.874	.073
	120	.651	.096	.908	.274
Jefferson County	42	.019	.109	.154	.335
	43	.022	.085	.579	.036
	175	.054	.089	.219	.212
San Juan County	44	.00	.105	1.468	.159
	45	.00	.365	.538	.432
	46	.00	.273	.448	.223
Okanogan County	71	.341	.112	2.084	.018
	74	.347	.288	4.679	.081
	76	.006	.096	.714	.011
	77	.019	.112	.614	.027
Whitman County	5	.635	.142	1.081	....
	72	.471	.361	.456	.256
	73	.322	.121	.332	.283

[a] Bul. 13, 23, and 55, Wash. Agr. Exp. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Washington—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Whatcom County	75	0.006	0.294	0.324	0.546
	78	.142	.285	.409	.000
	79	.021	.067	.359	.151
	139	.316	.139	1.234	.454
	140	.483	.084	1.044	.112
	141	.275	.144	1.326	.000
	142	.319	.265	.891	.014
Skagit County	82	.111	.089	1.049	.009
	83	.057	.070	.832	.005
	84	.006	.045	.891	.005
	85	.014	.144	.891	.007
	86	.129	.207	1.081	.006
	100	.186	.304	.474	Trace.
	101	.028	.205	.518	.018
Yakima County	91	.189	.128	2.389	.092
	92	.149	.174	.909	.068
	93	.310	.141	1.259	.364
	94	.047	.153	1.469	.421
	137	.455	.029	1.154	.013
King County	102	.004	.057	.389	....
	129	.057	.070	.599	.216
	179	.142	.390	.404	.189
Thurston County	176	.076	.320	.506	.235
Snohomish County	103	.051	.176	.414	.018
	177	.218	.237	.704	.322
	105	.145	.067	.564	.357
	122	.625	.344	1.214	.209
	111	.154	.240	.524	....
	162	.335	.137	.333	.054
	37	.003	.205	.569	....
Clallam County	111	.154	.240	.525	.023
	128	.171	.115	.834	.450
Spokane County	115	.550	.154	.432	.306
	198	.534	.216	.630	.036
	199	.385	.190	.600	.054
Okanogan County	218	.147	.245	27.540	.605
Walla Walla County	289	.378	.320	1.200	.400
	290	.465	.287	1.450	.399
	291	.485	.351	1.350	.345
	292	.440	.320	1.550	1.003
Franklin County	293	.437	.351	1.050	.299
	294	.393	.325	1.300	.362
Kitsap County	80	.085	.048	1.971	.018
	81	Trace.	.019	.308	.281
	124	.111	Trace.	.659	.032
	126	.054	.045	.534	.036
	106	.003	.029	1.296	.476
Experiment Station Farm	373	.107	.177	.150	.010
	374	.129	.136	.175	.148
	375	.117	.192	.005	.109
	376	.092	.135	.010	.091
	378	.020	.336	.220	.091
Thurston County	184	.188	.312	.638	.048
	102	.004	.058	.389	.561
	231	.189	.297	.450	.112
Pierce County	37	.003	.205	.569	.048
	219	.181	.192	.940	....
	220	.144	.409	.760	....
Snohomish County	212	.146	.217	1.140	.091
	221	.150	.307	.520	....
King County	200	.087	.159	.410	.016
Utah:[a]					
College Farm	90	.046	.115	3.45	2.29
	93	.051	.103	3.08	2.52
Cache Valley, south end	2067	1.04	.18	.83	.50
	2074	.62	.18	.69	.55
	2162	1.15	....	.60	.49
	2070	.74	.24	.86	.67
	2079	1.48	.39	1.66	2.42
	2062	.69	.24	2.10	.56
Cache Valley, west side, south half	2058	.77	.19	.84	.65
	2085	.76	.24	.85	.64
	2071	1.34	.21	1.00	.98
	2073	1.50	.27	1.01	.72

[a] Ann. Rep. Utah Agr. Expt. Sta. (1891); Bul. 52, Utah Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Utah—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cache Valley, west side, south half	2163	1.43	0.27	1.25	0.86
	2160	1.34	.25	1.28	1.16
	2166	1.09	.42	1.55	.51
Cache Valley, west side, north half	2061	.47	.14	.46	.21
	2078	.67	.18	.99	.67
	2063	.68	.16	.67	.33
	2064	.71	.20	.69	.49
	2081	1.37	.29	1.31	.50
	2065	1.51	.25	.06	.89
Cache Valley, north end	2169	1.18	.15	1.85	.88
	2167	1.56	.30	3.14	.67
	2057	.50	.25	.67	.13
Cache Valley, east side	2065	1.16	.20	1.68	.54
	90	.05	.12	3.45	2.29
	93	.05	.10	3.08	2.52
	2059	1.39	.18	2.22	1.47
Middle Cache Valley	2172	1.05	.21	7.35	1.37
	2046	.53	.20	1.50	.21
	2047	.50	.25	2.43	.58
	2048	.60	.18	.59	.73
	2049	.30	.18	.54	.33
	2050	.44	.20	.56	.41
	2051	.90	.25	1.24	1.52
	2052	.31	.18	.17	.62
	2053	.36	.15	.22	.47
	2084	.69	.13	.69	6.39
	2083	.20	.26	1.11	8.36
Sanpete Valley	1819	.27	.16	.37	.13
	1818	.68	.21	9.81	.73
	1817	.72	.11	10.65	.07
	1816	.80	.22	13.09	.84
	1821	.51	.17	22.54	1.29
	1824	.65	.15	17.35	.29
	1826	.95	.20	14.89	.42
	1827	1.24	.24	13.16	.26
	1808	.58	.17	9.91	1.40
	1807	.67	.18	9.53	1.68
	1809	1.03	.19	14.01	1.20
	1805	.58	.14	12.84	.71
	1806	.95	.16	22.05	.85
	1825	.81	.17	13.17	1.80
	1811	.75	.23	13.99	.46
	1812	.60	.20	13.24	.59
	1813	1.25	.16	13.76	.75
	1814	.95	.12	13.17	.29
Wyoming:[a]					
Laramie Experiment Farm	5	.56	.15	1.47	.14
	7	.64	.14	.82	.76
Lander Experiment Farm	37	.68	.15	.64	1.36
	51	.61	.20	6.63	1.65
Saratoga Experiment Farm	19	.64	.12	3.41	.95
	43	.73	.13	.74	1.15
Sheridan Experiment Farm	33	.52	.28	.69	.94
Sundance Experiment Farm	27	.68	.18	4.97	3.21
Wheatland Experiment Farm	21	.63	.14	.87	.85
Tennessee[b]	1	.120	.040	.053	.140
	2	.180	.074	.060	.213
	3	.330	.104	.180	.342
	4	.312	.057	.163	.455
	5	.092	.021	.050	.085
	7	.403	.017	.073	.291
	6	.340	.022	.100	.265
	8	.218	.010	.100	.090
	9	.410	.158	.510	.290
	10	.393	.078	.278	.355
	11	.285	.020	.093	.157
	12	.378	.026	.132	.184
	13	.409	.069	.212	.270
	14	.380	.071	.205	.246
	15	.416	.113	.199	.290
Greene County		.092	.021	.050	.085
Knox County		.181	.074	.060	.213
		.120	.040	.053	.140
Grundy County		.403	.017	.073	.291

[a] Bul. 6, Wyo. Agr. Expt. Sta.

[b] Bul. 3, Tenn. Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Tennessee—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Franklin County		0.340	0.022	0.100	0.265
Monroe County		.312	.057	.163	.455
Loudon County		.380	.104	.180	.342
Dyer County		.416	.113	.199	.290
Gibson County		.409	.069	.212	.270
Coffee County		.218	.010	.100	.090
Benton County		.285	.020	.093	.157
Carroll County		.378	.026	.132	.184
Fayette County		.380	.071	.205	.246
Maury County		.410	.158	.510	.290
Robertson County		.393	.078	.278	.35
New Hampshire [a]	1	.64	.36	.63	.62
	3_1	1.06	.16	.63	....
	3_2	1.06	.09	.76	.53
	5_1	.91	.08	.73	.74
	5_2	.97	.05	.77	.68
New York [b]	E	.95	.115	.60	1.02
	D	.89	.093	.62	.85
	D^2	.98	.134	.68	1.94
	F^1	1.04	.117	.70	1.04
Missouri [c]	1a	1.32	.08	.63	.44
	1b	1.23	.09	.55	.38
	2a	2.05	.07	.50	.45
	2b	1.90	.07	.50	.45
	3a	1.45	.06	.47	.29
	3b	1.45	.06	.42	.21
	4	1.72	.06	.62	.34
Nevada [d]	2	.364	.125	7.492	3.031
	3	.16	.040	9.580	2.332
	4	.128	.019	2.801	.574
	11	•.488	.210	9.056	3.776
	12	.364	.125	7.492	3.031
	13	.616	.030	1.990	1.339
	14	.470	.104	11.549	2.810
	15	.628	.178	17.831	8.404
Nevada [e]	1	.313	.479	1.86	1.03
	2	.306	.291	7.716	1.570
	3	.016	.040	9.580	2.332
	4	.302	.157	2.447	1.403
	5	.457	.223	7.223	1.283
	6	.227	.163	1.503	.690
	7	.128	.019	2.801	.574
	8	3.34	.215	1.407	1.314
	9	.277	2.292	1.900	1.521
	10	.682	.190	2.001	1.470
	1501	.81	.35	2.50	1.18
	1503	1.12	.35	2.90	.23
	1504	1.03	.32	5.00	.17
	1523	1.79	.30	4.15	.23
	1533	.68	.41	.80	4.14
	1534	1.05	.26	5.15	.22
	1508	.51	.45	4.35	1.29
	1509	.97	.73	2.70	.21
	1510	.73	.27	3.30	1.09
	1511	.42	.19	2.45	1.08
	1512	.91	.28	2.20	.26
	1513	.42	.38	1.85	Trace.
	1514	.92	.79	2.30	.18
	1515	.54	.38	3.90	1.55
	1518	.43	.19	12.00	2.34
	1519	.32	.35	7.99	1.67
	1520	.42	.32	2.40	1.10
	1521	Trace.	.30	1.55	.96
	1523	Trace.	.26	14.65	1.81
	1533	.72	.26	12.50	5.10
	1534	.45	.35	8.10	2.02
	1545	.46	.55	1.60	1.06
	1546	.32	.26	1.20	.45
	1547	....	.38	1.85	.45
	1548	.32	.26	1.20	.45
	1549	.40	.38	1.48	.34

[a] Ann. Rept. N. H. Agr. Expt. Sta. (1893).
[b] Ann. Rept. N. Y. Agr. Expt. Sta. (1889).
[c] Bul. 5, Mo. Agr. Expt. Sta.
[d] Bul. 19, Nevada Agr. Expt. Sta.
[e] Bul. 39, Nevada Agr. Expt. Sta.; Ann. Rept. Nevada Agr. Expt. Sta. (1890).

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
West Virginia[a]	12	0.243	0.153	0.104	....
	13	.593	.121	.335	....
	14	.808	.167	.451	....
	15	.403	.105	.181	....
	16	.705	.103	.062	....
	17	.481	.088	.065	....
	46	.250	.115	.081	....
	47	.516	.185	.404	....
	48	.459	.184	.116	....
	49	.781	.095	.059	....
	50	.888	.121	.076	....
	51	.401	.093	.11	....
	53	.479	.211	.081	....
Ohio:[b]					
East farm, Wooster	840	.25	.07	.35	0.30
	844	.24	.081	.30	.43
	830	.20	.08	.27	.48
	834	.28	.08	.29	.28
	800	.15	.064	.21	.43
	804	.15	.061	.25	.43
	810	.16	.101	.37	.42
	814	.14	.089	.23	.42
	820	.16	.11	.25	.40
	824	.19	.129	.33	.40
	850	.29	.07	.32	.23
	852	.27	.079	.20	.35
	854	.25	.08	.24	.44
	856	.24	.099	.28	.37
	858	.20	.118	.25	.43
	860	.28	.08	.30	.36
South farm, Wooster	872	.28	.151	.225	.368
	876	.27	.118	.187	.375
	862	.39	.167	.24	.45
	866	.29	.191	.20	.39
	868	.34	.156	.208	.358
University farm, Columbus	1	.64	.12	.64	.76
	4	.53	.20	.60	.52
	7	.62	.12	.59	.71
	10	.55	.17	.46	.64
	13	.59	.15	.45	.61
	16	.53	.10	.63	.58
	19	.62	.11	.68	.62
	22	.43	.12	.45	.49
Test farm, Strongville	1852	.18	.097	.20	.44
	1864	.25	.064	.16	.31
	1868	.22	.121	.10	.54
Test farm, Strongville	1874	.21	.099	.19	.34
	1880	.20	.08	.23	.40
	1884	.25	.12	.28	.40
	1810	.23	.197	.19	.42
	1820	.19	.161	.18	.56
	1826	.19	.113	.27	.461
	1832	.28	.227	.30	.57
	1838	.20	.126	.354	.44
	1844	.11	.126	.23	.54
	1846	.15	.121	.22	.50
Northwest test farm, Neapolis	1802	.50	.11	.11	.09
	1806	.50	.16	.49	.18
	1803	.60	.10	.80	.14
	1807	.60	.12	.41	.15
	1786	.046	.120	.07	.10
	1792	.060	.130	.31	.14
	1787	.040	.110	.07	.11
	1793	.090	.120	.22	.15
Germantown	4253	.142	.102	.11	.31
Carpenter test farm	4255	.193	.124	.18	.33
	4257	.181	.101	.18	.25
Wooster experiment farm, first 12 inches	....	.25	.80	.313	.356
Strongville, first 12 inches	....	.251	.145	.205	.474
Columbus, O. S. U., first 12 inches	....	.563	.143	.621	.623
Neapolis, first 12 inches	....	.043	.115	.070	.165

[a] Bul. 28 and 99, W. Va. Agr. Expt. Sta.

[b] Bul. 110 and 150, Ohio Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Oklahoma: [a]		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Virgin soil, Statute farm	7	0.44	0.06	0.95	0.21
Virgin soil	10	.80	.04	.44	.16
Virgin soil	5	.32	.06	.76	.18
Pennsylvania: [b]					
Donegal		.62	.191	.61	1.26
Rocky Springs		.67	.265	.41	2.05
Connecticut, [b] New Milford		.23	.22	.32	.78
North Carolina, [b] Granville County		.02	.02	.07	.02
Sumatra, [b] gray soil		.22	.11	.77	.37
Cuba: [c]					
San Antonio		.190	.555	.270	.190
Zorilla		.165	.475	.350	.210
South Carolina, [d] Spartanburg farm	13	.142	.057	.027	.081
	17	.090	.066	.037	.043
	15	.100	.011	.045	.110
Columbia farm	1	.171	.044	.019	.040
	3	.050	.107	.022	.072
	5	.089	.022	.046	.124
Darlington farm	19	.052	.034	.025	.043
	21	.050	.037	.062	.047
	23	.040	.051	.028	.003
Big River		.541	.155	.188	.811
Rhode Island: [e]					
Kingston plain		.155	.127	.569	.209
Kingston upland		.175	.106	.448	.264
Warwick		.124	.029	.410	.290
Lime Rock		.184	.092	1.295	1.141
Block Island		.136	.067	.273	.209
Middletown		.164	.099	.252	.368
East Providence		.126	.120	.495	.356
Tennessee: [f]					
Hamblen County	58	1.21	.37	.08	.13
	55	.10	.03	.10	.12
Knox County	606	.08	.03	.12	.22
	31	.14	.03	.09	.11
	48	.16	.05	.13	.20
Hamblen County	64	.23	.04	.16	.17
Knox County	25	.28	.09	.17	.15
McMinn County	172	.38	.06	.12	.37
Hamblen County	60	.28	.10	.04	.13
	66	.08	.01	.09	.11
Knox County	32	.29	.09	.11	.10
	602	.26	.08	.12	.22
	608	.09	.03	.08	.15
Hamblen County	51	.85	.10	.82	.42
	57	.36	.07	.17	.25
Knox County	29	.43	.07	.22	.24
	821	.26	.09	.10	.30
McMinn County	174	.68	.07	.31	.53
Roane County	595	.18	.07	.06	.12
Washington County	597	.18	.07	.10	.18
Anderson County	129	.21	.17	.12	.19
Hamblen County	49	.24	.08	.12	.24
Knox County	600	.36	.16	.30	.29
	603	.41	.18	.38	.73
	30	.34	.09	.20	.35
	37	.18	.16	.18	.31
	553	.18	.11	.16	.22
Roane County	593	.30	.09	.26	.33
Blount County	35	.52	.18	.17	.56
Hamblen County	53	.91	.09	.73	.96
Knox County	26	.45	.12	.43	.48
	612	.41	.09	.41	.52
Cumberland County	605	.06	.03	.10	.10
	746	.18	.06	.06	.27
	67	.08	.02	.04	.14
Cumberland County	68	.06	.03	.04	.16
Coffee County	750	.23	.07	.23	.21
Franklin County	39	.31	.09	.21	.30
	565	.27	.10	.16	.23
	566	.34	.04	.14	.27

[a] Bul. No. 5, Okla. Agr. Expt. Sta.
[b] Ann. Rep. Pa. Agr. Expt. Sta. (1894).
[c] Ann. Rep. Pa. Agr. Expt. Sta. (1901).
[d] Ann. Rep. S. C. Agr. Expt. Sta. (1889).
[e] Bul. 28, R. I. Agr. Expt. Sta.
[f] Bul. 3, Tenn. Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Tennessee—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Humphreys County	592	0.23	0.05	0.13	0.26
Lawrence County	569	.16	.08	.08	.21
	570	.28	.06	.08	.31
Montgomery County	742	.22	.05	.14	.23
Stewart County	581	.15	.05	.12	.18
	583	.17	.51	.15	.18
White County	571	.20	.06	.14	.16
	574	.22	.07	.13	.49
	563	.21	.07	.09	.28
	564	.32	.05	.14	.34
Coffee County	867	.09	.04	.14	.15
Dickson County	591	.16	.03	.08	.24
	589	.10	.03	.10	.15
	590	.31	.02	.02	.49
Houston County	585	.15	.03	.10	.19
	586	.12	.03	.04	.24
	583	.15	.05	.09	.18
	579	.13	.09	.34	.16
Lewis County	587	.18	.02	.06	.17
	588	.25	.04	.03	.35
Putnam County	843	.07	.03	.06	.11
Warren County	806	.14	.04	.09	.14
	575	.08	.01	.07	.13
	580	.11	.01	.07	.13
Bedford County	751	.28	.14	.09	.37
	615	.17	.08	.28	.19
	616	.15	.08	.25	.21
	572	.33	.12	.24	.33
	573	.49	.05	.31	.42
	577	.46	.19	.57	.44
	578	.19	.05	.05	.19
	747	.26	.16	.14	.24
	748	.30	.11	.10	.27
	170	.32	.26	.20	.32
	171	.42	.17	.18	.40
	175	.43	.14	.56	.36
	176	.43	.15	.61	.34
Davidson County	617	.70	.06	.45	.79
Lincoln County	42	.44	.31	.31	.53
Marshall County	561	.19	.32	.20	.30
	633	.25	.26	.17	.28
	660	.33	.27	.27	.35
Rutherford County	635	.29	.08	.22	.23
Smith County	822	.22	.21	.17	.21
Sumner County	634	.24	.20	.23	.26
	160	.33	.26	.38	.28
	161	.29	.25	.20	.38
Williamson County	567	.33	.32	.20	.32
	568	.59	.97	.18	.23
Carroll County	662	.21	.07	.16	.21
	661	.32	.05	.10	.41
Chester County	659	.20	.11	.19	.21
Dyer County	664	.24	.08	.16	.25
Gibson County	158	.21	.06	.16	.25
	159	.26	.06	.11	.37
	668	.23	.08	.23	.23
Hardeman County	670	.35	.09	.22	.33
Henderson County	658	.23	.07	.16	.21
Henry County	663	.23	.07	.15	.21
Madison County	749	.31	.09	.09	.43
McNairy County	671	.20	.06	.11	.19
Obion County	669	.28	.09	.39	.42
Weakley County	666	.23	.07	.20	.24
	665	.34	.06	.11	.40
	667	.28	.08	.16	.26
Blount County	135	.76	.24	.24	.52
Giles County	576	.34	.52	.38	.34
	584	.42	.70	2.25	.35
Roane County	594	.09	.04	.09	.23
White County	883	.22	.07	.13	.23
Montgomery County	871	.20	.05	.15	.23
	874	.38	.16	.25	.38
Maury County	885	.31	.21	.29	.35
Sumner County	873	40	.38	.43	.39

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Oregon:[a]		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Salem	2097	0.15	0.41	0.37	0.76
	2698	.20	.53	.48	.41
	2699	.26	.21	.80	.30
	2700	.12	.21	.54	.27
	2701	.44	.34	.32	.13
	2702	.39	.18	.45	.13
Hubbard	2097	.08	.24	.28	....
	2095	.14	.38	.31	....
	2096	.30	.40	.45	....
	2513	.19	.24	.71	.56
	2525	.21	.19	.68	.87
	2539	.20	.26	.78	.85
	2554	.28	.14	1.11	.56
	2591	.10	.45	.94	.48
	2592	.18	.23	.29	.11
	2616	.51	.20	1.26	.90
	2617	.30	.22	.84	1.27
	2618	.13	.20	1.22	.79
	2619	.25	.21	1.98	1.31
	2621	.17	.19	1.09	.71
	2627	.19	.12	1.18	.29
	2623	1.16	.23	1.92	1.00
	2635	.10	.38	.54	.33
	2637	.17	.31	.48	.46
	2638	.16	.39	.67	.39
	2644	.26	.20	.76	.73
	2649	.12	.41	.67	.28
	2650	.16	.34	.94	.29
	2656	.09	.16	.55	.60
	2658	.10	.38	2.89	.60
	2689	.18	.36	.59	.18
	2690	.28	.26	1.44	.55
	2691	.43	.30	.91	.80
	2710	.43	.43	.53	.00
	2751	.43	.18	.45	.00
	2754	.37	.31	1.40	.95
	2758	.38	.38	.24	.79
	2781	.34	.89	.31	.91
	2838	.39	.22	.67	.80
	2841	.13	.14	.85	.48
	2843	.38	.25	.77	.44
	2844	.27	.34	.91	.35
	2847	.44	.25	.74	.58
	2848	.14	.24	.43	.35
	2854	.26	.16	.88	.46
	2855	.52	.39	.69	.67
	2869	.31	.25	.68	.76
	2921	.97	.24	1.35	1.24
Beaverdam soils	1	.14	.26	1.09	.22
	2	.28	.31	.26	.06
	3	.13	.22	.47	.10
	4	.10	2.30	.92	.33
	5	.20	.21	1.18	.25
North Carolina:[b]					
Oxford	....	.161	.16	.240	.047
Washington:[c]					
Spokane County	564	.829	.249	7.768	3.891
	641	.438	.108	.320	.142
	642	.304	.157	.334	Trace.
	643	.356	.300	.524	....
	1030	.389	.185	.618	....
Stevens County	77	.492	.122	.741	.150
	78	.225	.048	.741	.239
	161	.074	.083	.400	.234
	342	.162	.280	.350	.175
	435	.193	.400	.506	.374
	436	.229	.343	.494	.602
	655	.412	.217	.640	1.218
	656	.320	.089	.590	.469
	673	.336	.192	.499	.515
	1103	.099	.082	36.009	.684

[a] Ann. Rep. Oregon Agr. Expt. Sta. (1905); Bradley Jour. Am. Chem. Soc., *28*, 64 (1906).
[b] Bul. 90, N. C. Agr. Expt. Sta.
[c] Bul 85, Wash. Agr. Expt. Sta.; Bul. 10, Div. of Chemistry, U. S. Dept. Agr., 1886.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Washington—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ferry County	446	0.204	0.124	0.581	0.548
	1872	.323	.257	.961	.262
	1873	.384	.241	.769	.216
Okanogan County	789	.294	.145	.668	.162
	790	.335	.170	.944	.319
Chelan County	158	.118	.078	.379	.301
	576	1.114	.122	1.365	.897
	1885	.518	.225	.714	.186
	1886	.649	.240	.852	.522
Lincoln County	741	.436	.117	.842	.581
	742	.524	.150	.755	.746
	1890	.517	.172	.563	.070
Douglas County	868	.335	.155	5.561	.976
	1024	.312	.050	1.120	.445
	1241	.298	.125	.568	.568
	1242	.442	.147	.762	.642
	1416	.382	.102	.563	.171
Adams County	1699	.450	.042	.618	.684
	1837	.411	.120	.591	.258
Whitman County	1888	.506	.187	.568	.194
Garfield County	1134	.567	.127	.726	.847
Asotin County	1133	.320	.080	.609	.632
	1420	.434	.052	.480	.239
	1431	.426	.042	.535	.095
	1432	.391	.047	.549	.210
Walla Walla County	1698	.358	.050	.824	.306
	1842	.413	.142	1.998	.140
	1845	.328	.037	.659	.104
	1846	.426	....	.770	.140
Columbia County	1135	.467	.110	.755	.793
	1411	.431	.162	.803	.437
	1412	.287	.152	.831	.509
Benton County	142	.427	.165	3.451	1.458
	708	.329	.105	1.570	1.009
	743	.312	.140	.944	.650
	745	.288	Trace.	.987	.712
	767	.301	Trace.	1.721	.940
	782	.415	Trace.	1.250	.582
Yakima County	194	.212	.136	1.631	.703
	545	.144	.130	1.770	1.270
	662	.293	.102	1.078	.500
	667	.125	Trace.	.648	Trace.
Kittitas County	722	.471	.112	1.190	.793
	723	.462	.063	2.134	.850
	751	.792	.187	14.912	4.830
Klickitat County	8	.359	.150	.663	.385
	9	.413	.184	.390	.416
	190	.147	.069	.365	.354
	512	.028	.032	.790	Trace.
	1025	.116	.067	.550	....
Skamania County	661	.385	.138	.540	.297
	1102	.318	.118	.452	....
Clarke County	172	.166	.243	.486	.547
	330	.066	.198	.200	....
	331	.178	.426	.862	.674
Wahkiakum County	602	.354	.212	.552	.228
	603	.610	.105	1.542	.982
	604	.134	.062	.145	....
Lewis County	783	.071	.062	.653	.405
	784	.162	.297	.769	.455
	785	.224	.107	.479	.086
	786	.124	.062	.421	.189
	1772	.184	.182	.164	.428
Chehalis County	143	.223	.118	.379	.256
	144	.144	.390	.393	.713
Mason County	869	.146	.155	1.525	.657
	1656	.440	.192	1.338	.703
	1657	.495	.192	1.433	.659
	1658	.475	.224	1.329	.465
	1659	.545	.224	2.099	1.411
	1660	.535	.216	1.418	.973
	1661	.940	.224	1.428	.947
	1662	.700	.224	1.449	.991
San Juan County	394	.154	.300	.873	.906
	870	.180	.125	1.060	.630
	871	.162	.087	1.031	.481

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Washington—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
King County	159	0.126	0.044	0.615	0.807
	160	.157	.073	.693	.548
	499	.125	.266	1.089	.398
	500	.153	.190	1.089	.658
	744	.193	.124	1.321	.602
Dakota:[a]					
Prairie soils	6	.720	.112	.848	.868
	16	.725	.112	.852	1.535
	7	.745	.224	3.898	2.007
Michigan:[b]					
Berrien County		.180	.715	.967	.267
Indiana:[b]					
Boone County		.510	.041	1.387	.771
New York:[b]					
Oswego County	A1	.320	.023	.350	.389
	A2	.425	.052	.440	.501
	A3	.305	.023	.350	.274
	A4	.595	.050	.564	.641
	B5	.400	.010	.753	.555
	B6	.475	.048	1.873	.868
	B7	.480	.038	.535	.642
	C8	.530	.176	.683	.893
	C9	.460	.176	.634	.746
Louisiana:[b]					
Rapides Parish	2574	1.470	.160	1.165	2.169
	2575	.930	.144	2.060	1.066
	2576	1.940	.193	.836	2.547
	2577	.805	.113	.414	1.131
	2579	.430	.097	.185	.346
	2580	.165	.00	.111	.090
	2581	.745	.080	.371	.839
	2582	.805	.096	.926	1.934
Nebraska:[c]					
Dawes County		.041	.822	1.892	.205
Cherry County		.410	.062	.498	.084
Brown County		.741	.062	.773	.060
Antelope County		.592	.039	.595	.031
Saunders County		.241	.112	.490	.334
Lancaster County		.197	1.421	.612	.420
Hamilton County		.054	.094	.468	.439
Mills Farm		.806	.137	1.007	1.080
Division B		.593	.156	.715	.860
Wisconsin:[d]					
Experiment plat—					
Poor		.26	.18	1.44	
Medium		.27	.20	1.35	
Good		.30	.22	1.05	
(Red Clay)	127	1.27	.08	.75	2.08
Clark County	61	.08	.17	.63	.73
University farm	119	.37	.13	.53	.80
Shicoton	71	.17	.27	.83	.56
Lacder Flambeau	48	1.81	.18	1.05	.57
Peat	21	.46	.25	1.74	.44
Muck	22	1.43	.23	1.82	1.47
Virgin soil, University farm		.37	.13	.53	.80
Texas:[e]					
Terrell		.17	.28	.55	.28
Pecan Gap		.83	.13	.81	.32
Forney		.316	.326	11.00	.543
Prairie soil		.837	.313	6.62	.81
Hammock		.68	.25	6.30	.46
Manor, Travis County		.576	.115	5.81	.317
Bell County, Waxie		.22	.12	23.98	.94
Bell County, Hammock		1.45	.18	1.03	.73
Waxahachie		.35	.15	5.17	.67
New Braunfels		.22	.41	7.32	1.31
Abilene		11.37	Trace.	4.04	1.40
Wichita		.426	Trace.	.074	Trace.

[a] Bul. 10, Div. of Chemistry, U. S. Dept. Agr., 1886 (locality unknown).
[b] Bul. 10, Div. of Chemistry, U. S. Dept. Agr., 1886.
[c] Bul. 60, Nebr. Agr. Expt. Sta.
[d] Ann. Rep. Wis Agr. Expt. Sta. (1905).
[e] Bul. Nos. 25, 35, 45, 61, 82, and 99, Texas Agr. Expt. Sta.; Ann. Rep. Texas Agr. Expt. Sta. (1889).

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Texas—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
El Paso		0.52	0.34	0.57	Trace.
		.43	.60	3.83	Trace.
Fort Bend		.46	.166	2.74	0.24
Brazoria		1.09	.136	1.66	.126
		.885	.34	5.66	1.85
		.545	Trace.	.600	.73
Brazos River		.885	.34	5.66	1.85
Brazos Bottom		.46	.166	2.74	.24
		.856	.136	1.66	.126
		.545	Trace.	.609	.73
Kaufman County		.68	.25	6.30	.46
		.316	.326	11.00	.543
		.887	.313	6.62	.81
Manor		.576	.115	.581	.317
New Braunfels		.22	.41	.32	1.31
Waxahachie		.35	.15	5.17	.67
Bell County		.22	.12	23.98	.94
		1.45	.18	1.03	.73
Pecan Gap		.83	.128	.814	.32
Terrell		.17	.82	.55	.28
Cherokee		.48	.243	.35	.126
Ridge soil		Trace.	.07	.16	Trace.
Pine Ridge		Trace.	Trace.	.00	.00
Tyler County		.06	.03	.44	.08
		Trace.	Trace.	.00	.08
		1.14	Trace.	4.04	1.41
Wichita County		.426	Trace.	.07	Trace.
College Clay		.80	.083	.60	.06
Alvin	1	.93	.024	.958	.464
	2	.46	.22	6.33	1.46
	3	.56	.15	8.17	2.01
Harris County		.17	.12	1.62	
Hitchcock	1		.04	.21	.695
	2		.035	.165	Trace.
	3		.037	.40	.08
	4		.019	.66	.122
Mesa		.397	.074	3.56	1.06
Beeville	1	.32	.04	.76	.47
	2	Trace.	.01	.67	.41
	3	Trace.	.06	.60	.13
Carsin's farm	14	.02	.04	.17	.09
	16	.05	.05	.08	.05
	18	.01	.008	.04	.08
Huntsville	1	.05	.07	.09	.08
	2	.06	.06	.07	.18
	3	.05	.07	.18	.18
Willis	1	Trace.	.01	.18	.14
	4	.06	.01	.20	.27
	5	.37	.04	.16	.18
	7	.01	.03	.16	.28
	9	.04	.01	.04	.09
	11	.05	.29	.06	.18
Rice soils	95	.08	.016	.24	.18
	96	.29	.036	.55	.50
	97	.137	.019	.53	.70
	137	.143	.026	.24	.26
	141	.06	.023	.09	.16
	206	.396	.025	2.17	.83
Harris County		.29	.156	.65	.27
Victoria County		.43	.093	1.05	1.09
Brazoria County		.78	.148	1.88	1.91
Brownsville		1.31	.204	14.43	1.53
Houston County—					
Norfolk sand		.10	.01	.28	.31
Fine sand		.13	.01	.10	.03
Fine sandy loam		.18	.02	.09	.11
Orangeburg fine sand		.14	.05	.14	.06
Fine sandy loam		.71	.05	.10	.08
Lufkin fine sand		.11	.03	.15	.63
Clay		.14	.01	.43	.07
Susquehanna fine sandy loam		.11	.03	.05	.09
Clay		.20	.02	.29	.29

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Texas—Continued.					
Anderson County—		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Norfolk sand	....	0.07	0.02	0.05	0.05
Fine sand	....	.10	.02	.06	.07
Fine sandy loam	....	.13	.01	.04	.05
Orangeburg fine sandy loam	....	.13	.03	.02	.04
Clay	....	.22	.06	.23	.22
Yazoo clay	....	.50	.14	3.14	.75
Lamar County—					
Orangeburg sandy loam	....	.25	.05	.12	.07
Fine sandy loam	....	.76	.02	.06	.07
Silt	....	.78	.12	1.52	.61
Clay	....	.40	.05	.08	.20
Houston black clay	....	.39	.05	1.05	.89
Clay	....	.19	.02	.35	.32
Sharkey clay	....	.83	.11	1.20	1.25
Lufkin clay	....	.13	.03	.07	.11
Sanders loam	....	.12	6.04	.38	.25
Travis County—					
Houston black clay	....	.29	.07	5.66	.68
Yazoo sandy loam	....	.28	.07	10.60	1.06
Travis gravelly loam	....	.52	.04	1.47	.16
Lufkin fine sandy loam	....	.11	.02	.91	.10
Bexar County—					
Norfolk sand	....	.05	.02	.04	.02
Sandy loam	....	.17	.02	.05	.14
Houston black loam	....	.80	.06	3.06	.73
Clay	....	.32	.08	1.16	1.83
Orangeburg fine sand	....	.25	.02	.18	.01
Clay	....	.45	.09	.35	.35
Portsmouth sandy loam	....	.23	.03	3.40	.37
San Antonio clayey loam	....	.47	.08	8.06	4.01
Austin fine sandy loam	....	.03	.11	23.64	.62
Hays County—					
Houston loam	....	.29	.01	.37	.23
Black clay	....	.20	.08	19.61	.62
Clay	....	.04	.09	19.32	.44
Crawford sandy clay	....	.58	.18	12.40	.30
Silt clay	....	.78	.10	1.58	.83
Blanco loam	....	.05	.12	34.91	.91
Susquehanna fine sandy loam	....	.34	.40	.70	.20
Wabash clay	....	.41	.15	9.86	.96
Rio Grande Valley	1	....	.12	3.53	Trace.
	2	....	.29	2.06	.15
	3	....	.36	3.79	Trace.
Tyler County	....	.06	.03	.44	.08
Cherokee County	....	.48	.03	.36	.14
Arkansas [a]	14727	.17	.07	.10	.14
	14728	.36	.10	.08	.29
	14729	.15	.07	.10	.20
	14730	.34	....	.07	.22
	15353	.22	.16	.15	....
	15354	.30	.09	.08	....
California [a]	6356	1.07	.37	1.49	2.97
	6359	1.12	.53	1.47	3.39
	6831	.09	.05	.26	.21
	7936	.40	.16	4.46	1.75
	8051	1.81	.02	1.36	....
	8063	1.52	.05	1.06	....
	10147	.72	.14	.66	1.00
	3432	.33	.05	1.20	1.74
	6621	.92	.25	1.98	1.89
	6035	.11	.03	.67	.90
	6330	1.13	.30	1.29	2.22
	6352	1.84	.23	1.34	2.52
Miscellaneous	....	.55	....	2.82	1.18
	....	.31	....	2.20	1.53
	....	.54	....	1.96	1.73
	....	.29	.06	....	....
	....	.48	.06	1.79	....
	....	.34	.03	....	....
	....	1.20	.21	1.92	....
	....	1.01	.09	1.61	....

[a] Analyses made by the Bureau of Soils, U. S. Dept. of Agr.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Colorado [a]	7962	0.52	0.22	4.26	1.13
	7964	.61	.26	5.49	1.09
	723a	.71	.36	1.13	....
Miscellaneous	....	.88	.06	5.14	.60
	....	.57	.09	1.52	.19
	....	.89	.13	2.54	.45
	....	.82	.08	4.05	.20
	....	.80	.11	2.03	.28
	....	.79	.12	2.23	.21
	....	1.27	.22	2.10	.23
	....	.68	.22	.63	.48
	....	1.02	.22	2.74	.62
	....	.72	.11	.80	.13
	....	.61	.15	.40	.62
	....	.81	.22	.54	.19
	....	.89	.35	3.60	.80
	....	.54	.30	6.00	.36
	....	.56	.24	.45	.40
District of Columbia [a]	6548	.53	.07	.57	.19
	726a	.29	.07	.26	.02
	727a	.29	.07	.26	.02
	728a	.36	.05	.26	.01
Florida [a]	2822	.04	.93	.24	.07
	3965	.03	....	.03	.16
	5284	.20	.02	.10	.07
	5286	.17	.08	.12	.05
	5288	.18	.02	.07	.06
	5290	.19	.03	.15	.07
	5391	.04	.05	.12	.01
	5392	.05	.04	.08	.02
	5403	.06	.04	.05	.01
	5404	.07	.06	.02	.02
	5405	.07	.04	.06	.01
	5406	.09	.09	.04	.03
	5407	.11	.19	.07	.08
	5408	.07	.17	.15	.02
	5409	.08	.08	.21	.02
	5410	.10	.08	.05	.03
	5413	.09	.06	.12	.01
	5414	.05	.04	.09	.02
Georgia [a]	6263	.12	.06	.14	.15
	6364	.09	.05	.09	.12
Kansas: [a]					
Miscellaneous	....	.18	.09	....	....
	....	.54	.10	2.84	.66
	....	.26	.11	....	.36
	....	.20	.13	3.23	.62
	....	.53	.11	.17	....
Kentucky [a]	7565	.28	.03	.05	.08
	13715	.39	.05	.24	.40
	13716	.31	.05	.24	.43
	13717	.23	.05	.29	.37
	13718	.29	.04	.23	.41
	1095	1.06	.25	.23	.51
Louisiana [a]	733	.71	.19	.54	.57
	734	.76	.18	.66	.70
Maryland [a]	132	.41	....	.44	.69
	5460	.38	.08	.21	.34
	5459	.91	.11	.11	.18
	5456	.44	.10	.11	.47
	5455	.89	.05	.15	.40
	5454	.86	.09	.14	.14
	1099	.46	.20	1.26	....
	749a	.15	.04	.09	....
	864a	.08	.04	.09	.03
Minnesota [a]	15355	.73	.24	6.45	....
	15356	.63	.17	13.83	....
	15357	.15	.24	1.22	....
	15358	.15	.15	1.07	....
	15359	.14	.23	1.03	....
	15360	.17	.13	.60	....
Mississippi [a]	7935	.31	.24	.83	1.22

[a] Analyses made by the Bureau of Soils, U. S. Dept. of Agr.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Nebraska [a]	....	0.91	0.19	2.35	1.22
	....	.96	.26	1.95	.42
	....	.99	.26	3.07	.65
	....	.54	.29	2.35	.47
	2089	.10	.30	.24	.03
	6832	.08	.02	.19	.09
New Jersey [a]	....	1.20	.28	.24	....
	5685	1.09	1.25	1.27	3.23
Nevada: [a]					
Miscellaneous	....	.72	.12	1.45	1.23
	....	.69	.20	1.81	1.60
	....	.99	.17	1.86	1.42
	....	.66	.20	1.56	1.31
	....	1.07	.16	1.78	1.48
	....	.73	.15	1.70	1.21
	....	.92	.21	1.80	1.51
North Dakota [a]	6549	.92	.10	.92	1.37
Pennsylvania [a]	1119a	.35	.16	.08	....
	....	.30	.17	.09	....
State College	....	.46	.12	.31	.54
	....	.40	.11	.26	.47
	....	.47	.11	.23	.46
	....	.42	.12	.25	.41
	....	.47	.11	.25	.42
	....	.40	.01	.25	.45
	....	.44	.03	.26	.55
	....	.44	.13	.24	.52
	....	.26	.11	.33	.44
	....	.35	.16	.34	.43
	....	.49	.13	.29	.56
	....	.43	.11	.25	.55
	....	.38	.11	.23	.42
	....	.41	.12	.24	.45
	....	.42	.11	.24	.50
	....	.39	.14	.27	.50
	....	.40	.11	.26	.53
	....	.38	.13	.23	.49
	....	.30	.15	.36	.47
	....	.26	.12	.31	.38
South Carolina [a]	3961	.02	.76	.59	.26
Texas [a]	2165	.13	.02	.07	.06
	2167	.08	.02	.15	.16
	808a {	.06	.03	.22	.09
		.02	.02	.27	.09
	790a	.82	....	7.25	1.17
	12481	1.64	.14	2.67	....
	12482	1.20	.10	6.88	....
Virginia: [a]					
Miscellaneous	....	1.02	.16	.14	....
	40004	.06	.30	.09	.18
Washington [a]	6546	.57	.11	1.11	1.01
Wisconsin [a]	798a	1.51	.05	.37	....
California: [b]					
Eldorado County	1638	.55	.23	.52	.38
Stanislaus County	1901	.98	.05	.61	.51
	1900	.49	.05	.61	.51
Tulare County	1903	.97	.15	.79	1.22
	1904	.87	.05	.73	.64
Ventura County	1910	.84	.14	.74	1.27
Los Angeles County	1820	1.60	.31	2.73	2.87
	1908	.41	.23	1.95	2.04
	1906	1.18	.21	2.66	1.79
	1907	1.01	.15	2.49	1.75
Inyo County	1756	.46	.08	.95	.79
Eldorado County	2214	.31	.15	.38	.69
Shasta County	2181	.40	.06	1.34	.67
Modoc County	2169	.41	.25	3.65	2.55
Glenn County	2291	.23	.22	1.53	.42
Yuba County	2403	.42	.20	.72	1.45
	2405	.42	.14	.97	1.83
Humboldt County	2319	.61	.30	.44	1.76

[a] Analyses made by the Bureau of Soils. U. S. Dept. of Agr.
[b] Ann. Rep. Cal. Agr. Expt. Sta., 1895-1397, 1901-3.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
California—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Mendocino County	2243	0.95	0.15	1.40	2.55
	2433	1.41	.28	1.09	2.35
Lake County	2301	.61	.08	2.51	1.37
	2295	.84	.12	2.34	.50
Contra Costa County	2454	.53	.07	4.50	1.83
Alameda County	1880	1.17	.19	1.38	2.68
	2430	.33	.07	.76	.76
San Luis Obispo County	2061	.67	.71	2.11	2.26
Ventura County	2273	.49	.06	.35	.89
Riverside County	2234	1.00	.16	1.50	1.64
San Diego County	1936	.18	.11	1.47	.58
Riverside County	2470	.80	.14	2.69	.75
	2471	1.26	.21	2.71	2.20
San Diego County	2324	.76	.23	4.35	1.24
	2325	.74	.22	3.75	1.68
Florida,[a] Dade County	10	.0965	.0240	.0250	.0090
	14	.0043	.0240	.1275	.0612
	19	.0178	.0256	.0725	.0351
	18	Trace.	.0304	.5500	.0036
Lee County	1	.0164	2.5630	6.6050	.0290
	25	.0058	.0208	Trace.	.0299
	26	Trace.	.0496	.0725	.0198
	28	.0125	.0112	.0000	.0117
	59	.0024	.0128	.0700	.0261
De Soto County	4	.0212	.0160	.0750	.1125
	64	.0072	.0928	.0000	.0369
Brevard County	12	.0086	.0336	.2100	.0225
	13	.0111	.0192	.1075	.0099
	21	.0612	.0544	2.2325	.0207
	38	Trace.	.0416	.0400	.0090
	40	.0034	Trace.	.0000	.0634
	X	.0198	.0333	.1150	.0197
Osceola County	47	.0077	.0032	.0225	.0144
	49	.0073	.0096	.0150	.0252
	51	Trace.	.0144	.0600	.0234
Polk County	42	.0038	.0064	.0000	.0090
	43	Trace.	.2768	.0125	.0531
	44	Trace.	2.4000	.1125	.0990
	45	.0028	.3112	.0175	.0414
	55	Trace.	.0272	.0125	.0261
	57	Trace.	.0240	.0000	.0162
Hillsboro County	75	.0028	.3408	.2025	.0693
	116	.0023	.0880	.2650	.0126
Pasco County	73	.0048	.1360	.0250	.0126
Orange County	31	Trace.	.1328	.0275	.0369
	60	Trace.	.0816	.0000	.0270
	62	.0193	.0272	.0000	.0036
	Y	.0160	.1175	.0625	.0175
Volusia County	6	.0048	.0112	.0500	.0297
	8	.0164	.0577	.0225	.0275
	Z	.0208	.1660	.0526	.0145
Marion County	33	.0149	.2544	.1500	.0198
Florida:[b]					
Miami	1296	.0135	.0162	.1740	.0176
	1298	.0170	.0075	.1587	.0222
	1300	.0170	.0062	.0312	.0149
Bocaratone	1302	.0097	.0087	.0187	.0000
	1304	.0145	.0087	.0062	.0000
West Palm Beach	1306	.0140	.0087	.0087	....
	1308	.0048	.0100	.0037	....
	1310	.0097	.0087	.0062	.0062
	1312	.0145	.0137	.0287	.0158
Jensen	1314	.0061	.0120	....	.0095
	1316	.0073	.0056	.0112	.0049
	1318	.0061	.0087	.0087	.0058
Eldred	1320	.0110	.0431	.0862	.0511
	1322	.0134	.0106	.0137	....
St. Petersburg	1380	.0134	.0056	.0162	.0058
	1382	.0134	.0556	.0312	.0357
Oneco	1384	.0122	.0106	.0187	.0163
Punta Gorda	1386	.0170	.0187	.0850	.0171
	1388	.0110	.0050	.0475	.0144
Orlando	1390	.0158	.0250	.0350	.0432
Key	1411	.2963	.9459	4.7259	1.5758

[a] Bul. 43, Fla. Agr. Expt. Sta.

[b] Bul. 68, Fla. Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Idaho:[a]		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Kootenai County	9	....	Trace.	1.32	0.03
	20	....	0.45	.94	1.16
Latah County	17	0.59	.49	2.80	.51
	19	.61	1.57	.13	.19
Shoshone County	5	.04	.35	.78	.72
Nez Perce County	31	.034	.25	3.75	.91
Grangeville	13	.04	.62	1.49	2.52
	14	.40	.01	1.44	.34
	15	1.92	.01	.64	.22
Canyon County	1	....	.31	2.70	.58
	6	....	1.20	.69	1.60
	7	....	.09	Trace.	.57
	8	....	.19	.65	.38
Bingham County	21	1.16	1.39	.07	.31
	22	1.22	.47	2.59	.29
	23	1.28	.41	2.15	.14
	24	.99	1.16	2.08	1.25
	25	1.04	.21	.06	1.09
Bear Lake County	26	1.44	.31	1.43	.37
	27	.72	.19	3.94	3.15
	29	1.12	.05	.59	3.15
	30	.72	.94	5.92	1.24
Cassia County	4	.775	.183	1.971	1.387
	5	.695	.137	1.870	1.322
Cœur d'Alene	7	.440	.188	.533	1.290
	9	.467	.205	.432	1.527
Nez Perces	11	.459	.188	.507	.905
American Ridge	....	.684	.157	.557	.997
Latah County	13	.673	.131	.722	1.019
	14	.557	.026	.767	.802
Lewiston	15	.526	.148	.872	1.150
Moscow	16	.563	.192	.939	.886
	18	.667	.176	.999	.766
Boise	20	.789	.237	1.567	1.090
	21	.896	.184	.893	1.006
	22	.459	.141	.465	.535
	23	.572	.143	.780	.831
Louisiana:[b]					
Calhoun	1	.023	.037	.085	.018
	2	.029	.048	.145	.074
	3	.011	.021	.027	.027
	5	.008	.011	.009	.011
Monroe	7	.069	.072	.128	.180
	9	.023	.007	.040	.036
Mississippi:[c]					
Agricultural College	48	.125	.148	.45	.32
	50	.153	.092	.161	.12
	49	.122	.092	.161	.12
	51	.126	.114	.307	.47
	52	.303	.204	.400	.68
	53	.104	.156	.770	.60
	54	.127	.233	.370	.47
	55	.132	.149	.610	.60
	56	.117	.182	.440	.60
	57	.097	.185	.64	.56
	58	.131	.102	.54	.39
	59	.150	.147	.83	.79
	60	.111	.096	.40	.53
	61	.145	.181	.63	.40
	62	.116	.118	.39	.12
	162	.12	.08	.14	.10
	163	.06	.08	.22	.06
Union County	606	.31	.089	.86	.061
Jackson County	692	.050	.027	.16	.072
	694	.056	.015	.23	.064
	695	.080	.004	.20	.028
Chickasaw County	888	.10	.26	.27	.22
Covington County	1522	.09	.184	.302	.318
	1523	.08	.100	.280	.126
Noxubee County	1524	.18	.24	4.91	.144
Oktibbeha County	1536	.25	.097	.47	.38
Tallahatchie County	1538	.46	.257	.94	.25

[a] Buls. 9 and 28, Idaho Agr. Expt. Sta.
[b] Special Rep. on the Geology and Agriculture of the Hills of La., La. Agr. Expt. Sta. (1892).
[c] Ann. Rep. Miss. Agr. Expt. Sta., 1895 and 1898–99; Bul. 65, Miss. Agr. Expt. Sta.

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Mississippi—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Hinds County	1544	0.10	0.07	0.66	0.36
Oktibbeha County	1572	.22	.192	1.85	.302
Holmes County	1696	.24	.190	.35	.08
Crystal Springs	928	.07	.07	.175	....
Coffeeville	400	.20	.09	.27	.24
	401	.18	.09	.22	.28
	402	.09	.06	.15	.17
	403	.17	.08	.19	.25
	404	.14	.06	.19	.19
Yazoo City	421	.365	.127	2.14	.11
Como	75	.143	.27	.88	.023
	76	.147	.232	.084	.033
Elizabeth	269	.55	.16	.34	.20
Noxubee County	937	.218	.085	.985	....
	939	.478	.189	1.56	....
	940	.463	.121	1.45	....
	941	.426	.121	1.13	....
	948	.360	.046	.990	....
	935	.201	.090	.325	....
	946	.450	.105	.945	....
	949	.372	.105	.485	....
	951	.245	.079	.325	....
	942	.400	.263	1.18	....
	943	.500	.302	15.57	....
	944	.509	.321	5.24	....
	945	.574	.296	5.15	....
Oktibbeha County	585	.460	.300	.630	....
	617	.300	.144	1.88	....
	620	.280	.093	5.90	....
	621	.360	.262	1.03	....
	622	.210	.108	.380	....
	583	.380	.427	.315	....
	594	.200	.108	.280	....
	595	.420	.229	.190	....
	597	.165	.147	.32	....
	585	.460	.300	.630	....
Copiah County	801	.203	.064	.150	....
	822	.200	.040	.155	....
Madison County	881	.257	.040	.165	....
	884	.180	.042	.145	....
	886	.225	.039	.265	....
Amite County	1021	.125	.055	.095	....
Wilkinson County	1026	.166	.033	.080	....
Panola County	994	.241	.055	.140	....
	983	.322	.064	.125	....
	976	.293	.102	.170	....
Oktibbeha County	833	.337	.079	.185	....
Choctaw County	904	.246	.075	.160	....
Leake County	844	.189	.050	.205	....
Scott County	850	.150	.049	.185	....
Choctaw County	906	.197	.037	.105	....
Winston County	911	.133	.022	.100	....
Neshoba County	836	.247	.087	.165	....
Scott County	853	.270	.097	.235	....
	855	.210	.044	.100	....
Winston County	913	.160	.044	.155	....
Kemper County	919	.199	.060	.130	....
Harrison County	674	.098	.033	.180	....
Jones County	1010	.123	.046	.200	....
	1012	.160	.035	.150	....
	1013	.208	.024	.111	....
Kemper County	926	.076	.110	.192	....
	928	.465	.156	1.68	....
	929	.185	.072	.980	....
	931	.263	.053	.535	....
Noxubee County	932	.442	.188	.960	....
	933	.148	.084	.210	....
	935	.201	.090	.325	....
	937	.218	.085	.985	....
	939	.478	.189	.156	....
	940	.463	.121	.145	....
	941	.426	.121	1.130	....
	942	.400	.263	1.18	....
	943	.500	.302	15.57	....
	944	.509	.321	5.24	....

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Mississippi—Continued.					
Noxubee County	945	0.574	0.296	5.15	....
	946	.450	.105	.945	....
	948	.360	.046	.990	....
	949	.372	.105	.485	....
	951	.245	.079	.325	....
Lowndes County	1153	.358	.111	3.56	....
	1154	.387	.140	3.71	....
	1155	.283	.093	.315	....
	1157	.268	.123	.360	....
Oktibbeha County	581	.39	.096	.11	....
	584	.92	.57	1.06	....
	585	.46	.30	.63	....
	586	.210	.115	.235	....
	593	.177	.14	.180	....
	594	.20	.108	.23	....
	595	.42	.229	.19	....
	597	.165	.147	.32	....
	617	.30	.144	1.88	....
	620	.28	.093	5.90	....
	621	.36	.262	1.03	....
	622	.21	.108	.38	....
	1106	.491	.328	2.69	....
	1107	.470	.143	.265	....
	1108	.423	.274	2.25	....
	1117	.360	.086	.950	....
	1118	.480	.121	12.52	....
	1119	.181	.105	.117	....
	1121	.152	.097	.175	....
	1122	.150	.083	.100	....
	1111	.215	.055	.800	....
	1113	.305	.070	1.06	....
	1280	.276	.075	.960	....
	1124	.454	.332	.260	....
	1126	.177	.119	.170	....
	1114	.398	.114	1.20	....
	1115	.262	.080	.800	....
	1158	.331	.188	.940	....
Clay County	1159	.193	.051	.650	....
	1161	.395	.184	1.53	....
	1162	.369	.244	1.24	....
	1163	.302	.207	1.36	....
	1165	.258	.113	.430	....
Monroe County	1168	.502	.191	1.82	....
	1169	.364	.109	1.11	....
	1172	.401	.174	6.26	....
	1174	.208	.089	1.59	....
	1175	.370	.153	.680	....
Chickasaw County	1178	.305	.115	1.06	....
	1179	.198	.036	.6'5	....
	1180	.258	.054	.890	....
	1181	.402	.140	5.80	....
	1182	.135	.047	.160	....
	1274	.189	.056	.110	....
	1276	.262	.064	.150	....
Lee County	1184	.385	.160	1.20	....
	1185	.340	.134	.815	....
	1186	.321	.210	1.61	....
	1187	.216	.210	3.27	....
	1189	.297	.237	1.27	....
	1190	.395	.194	1.47	....
	1191	.158	.068	.235	....
	1193	.402	.185	.940	....
	1194	.269	.118	.470	....
	1200	.200	.083	.500	....
	1202	.250	.076	.340	....
	1204	.096	.032	.053	....
	1206	.179	.253	9.63	....
	1209	.129	.055	.160	....
	1213	.086	.025	.030	....
Prentiss County	1211	.220	.090	.510	....
	1217	.098	.036	.190	....
	1219	.103	.043	.120	....
	1221	.102	.065	.120	....
	1223	.321	.329	11.93	....
	1225	.226	.129	.810	....

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Mississippi—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Prentiss County	1227	0.273	0.174	0.340	....
	1229	.105	.009	.070	....
	1234	.088	.018	.072	....
	1250	.089	.027	.205	....
	1253	.359	.092	1.32	....
	1254	.122	.051	.160	....
	1256	....	.114	1.05	....
	1257	.565	.140	.830	....
Alcorn County	1241	.147	.071	.235	....
	1245	.185	.051	.245	....
	1247	.129	.040	.175	....
	1248	.157	.050	.140	....
Union County	1261	.276	.048	.190	....
	1263	.187	.035	.160	....
	1265	.170	.038	.190	....
	1266	.203	.052	.140	....
	1268	.258	.093	.205	....
	1030	.190	.024	.110	....
Pontotoc County	1269	.336	.167	.142	....
	1272	.333	.094	.106	....
Alcorn County	1236	.178	.072	.145	....
Madison County	625	.215	.062	.29	....
	629	.20	.076	.22	....
	633	.170	.083	.17	....
	879	.250	.061	.120	....
	881	.257	.040	.165	....
	883	.396	.068	.145	....
	884	.180	.042	.145	....
	876	.326	.022	.300	....
	886	.225	.039	.265	....
Leake County	890	.281	.018	.110	....
	892	.160	.019	.110	....
	894	.165	.022	.025	....
	895	.093	.016	.05	....
Attala County	897	.190	.030	.115	....
	898	.229	.044	.210	....
	900	.160	.047	.130	....
	902	.105	.013	.050	....
Choctaw County	904	.246	.075	.160	....
	905	.177	.024	.050	....
	906	.197	.037	.105	....
Carroll County	958	.363	.080	.120	....
	960	.276	.188	.135	....
	961	.222	.104	.160	....
	963	.298	.051	.100	....
	965	.408	.078	.110	....
	967	.436	.090	.120	....
	969	.170	.050	.125	....
Yalobusha County	971	.180	.023	.015	....
	973	.311	.044	.065	....
	974	.212	.053	.140	....
Panola County	975	.223	.063	.145	....
	976	.293	.102	.170	....
	977	.335	.168	.200	....
	978	.333	.117	.130	....
	979	.323	.070	.190	....
	981	.426	.064	.170	....
	983	.322	.064	.125	....
	985	.373	.089	.185	....
Tate County	988	.304	.135	.120	....
	991	.183	.066	.190	....
	994	.241	.055	.140	....
	996	.262	.064	.220	....
	997	.303	.071	.165	....
	1000	.43	.097	.050	....
	1001	.26	.069	.150	....
Marshall County	1003	.253	.041	.300	....
	1007	.360	.083	.225	....
	1008	.252	.079	.275	....
Amite County	1021	.125	.055	.095	....
	1023	.17	.067	.175	....
	1025	.242	.057	.125	....
	1026	.166	.033	.08	....

Chemical composition of the soils of the United States, Great Britain and Ireland, France, and Germany, etc.—Continued.

CHEMICAL COMPOSITION OF THE SOILS OF THE UNITED STATES—Continued.

State or Territory.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
Mississippi—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Hinds County	871	0.168	0.040	0.190	....
	873	.182	.057	.210	....
	875	.277	.050	.105	....
Neshoba County	834	.170	.052	.075	....
	836	.247	.087	.165	....
	838	.163	.045	.080	....
Scott County	853	.270	.097	.235	....
	855	.210	.044	.10	....
	856	.309	.058	.20	....
	848	.190	.025	.095	....
	849	.202	.066	.285	....
	850	.150	.049	.135	....
Leake County	844	.189	.050	.205	....
	846	.165	.048	.170	....
Scott County	852	.130	.082	.085	....
Neshoba County	954	.563	.117	.300	....
Copiah County	801	.203	.064	.15	....
	803	.223	.058	.0[illegible]5	....
	805	.297	.064	.175	....
	807	.190	.061	.175	....
	809	.170	.040	.140	....
	810	.286	.047	.1[illegible]5	....
	811	.263	.068	1.20	....
	813	.173	.05	.0[illegible]0	....
	816	.300	.107	.255	....
	818	.196	.149	.225	....
	820	.233	.081	.215	....
	822	.200	.040	.155	....
	823	.277	.065	.120	....
	824	.253	.050	.285	....
	825	.251	.060	.100	....
	826	.262	.077	.150	....
	827	.128	.064	.095	....
	828	.134	.047	.115	....
	830	.199	.060	.130	....
	831	.264	.064	.125	....
Jones County	832	.132	.036	.125	....
	1010	.123	.046	.20	....
	1012	.160	.035	.15	....
Harrison County	674	.098	.033	.18	....
Winston County	913	.160	.044	.155	....
	915	.145	.055	.160	....
Kemper County	917	.140	.074	.068	....
	919	.199	.060	.130	....
Winston County	911	.133	.022	.100	....
Neshoba County	921	.090	.028	.020	....
Kemper County	923	.141	.019	.070	....
	925	.345	.029	.170	....
Scott County	858	.129	.013	.195	....
	859	.255	.029	.725	....
Rankin County	861	.290	.052	.220	....
	862	.194	.040	.185	....
	864	.240	.080	.115	....
	865	.230	.097	.125	....
	867	.193	.062	.125	....
Oktibbeha County	833	.337	.079	.185	....
Rankin County	869	.115	.057	.15	....
Washington County	269	.55	.16	.34	....
Bolivar County	676	.46	.17	.126	....
	677	6.87	.192	.92	....
	678	6.92	.195	.89	....
	679	.941	.216	.97	....
Coahoma County	700	.54	.092	.40	....
	701	.54	.14	.41	....
	702	.84	.134	.59	....
	703	.36	.115	.34	....
Jasper County	658	.415	.118	.372	....
	659	.50	.109	.245	....

Chemical composition of the soils of Great Britain and Ireland.

ENGLAND.

County.	Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Dorset[a]	Alluvium	38	0.46	0.42	3.84	0.48
		62	.22	.23	1.30	.11
		41	.81	.46	1.09	.26
	Gravel	36	.22	.32	.71	.45
		37	.33	.28	.64	.27
		63	.18	.26	.11	.04
		64	.17	.20	.11	.05
	Bagshot beds	83	.19	.18	.37	.02
		30	.13	.25	1.43	.34
		40	.18	.20	.80	.17
		65	.13	.12	.08	.06
	London clay	80	.23	.32	.37	.12
		12	.22	.47	1.26	.31
		68	.20	.15	.36	.07
	Reading beds	81	.27	.33	.66	.27
		11	.27	.40	1.57	.68
		67	.24	.21	.65	.07
		61	.06	.11	.33	.02
	Junction Reading beds and chalk.	39	.24	.42	1.83	.27
	Chalk	15	.25	.30	41.00	.83
		71	.27	.29	38.78	.65
		99	.19	.78	31.50	.53
		95	.29	.47	31.05	.11
		51	.20	.33	32.10	.27
		94	.22	.49	14.22	.15
		35	.28	.24	5.59	.71
		50	.39	.36	35.70	.27
		16	.59	.33	33.40	.71
		72	.50	.27	10.31	.43
		49	.20	.31	2.22	.19
		21	.39	.25	1.81	.39
		100	.38	.51	1.40	.47
		1	.17	.44	.90	.41
		98	.47	.36	1.01	.39
		96	.42	.31	1.30	.06
		97	.57	.26	.34	.28
	Greensand	79	.35	.37	.44	.08
		47	.81	.60	.92	.46
		48	.74	.79	7.10	1.00
		2	.40	.23	2.19	.59
	Junction green sand and marlstone.	31	.27	.32	1.45	.27
		25	.29	.28	.71	.68
	Wealden beds	33	.31	.31	1.02	.41
		32	.25	.44	1.36	.34
		84	.24	.29	.66	.32
		69	.36	.28	.96	.11
		22	.31	.50	.92	.27
	Purbeck beds	27	.34	.29	1.82	.48
	Portland stone	66	.46	.43	.51	.07
	Kimmeridge clay	3	.30	.15	2.10	.55
		20	.4	.6	2.10	.5
		42	.47	.89	2.22	.09
		85	.61	.38	2.52	.43
		86	.81	.24	1.87	.51
		87	.95	.34	1.76	.42
		88	.92	.50	1.18	.51
	Coral rag	19	.38	.31	.67	.96
		77	.63	.32	6.35	.54
		82	.39	.47	10.53	.54
		89	.53	.60	18.65	.60
		8	.27	.40	20.70	.36
		57	.68	.35	2.03	.69
		58	.49	.32	12.05	.20
	Calcareous grit	9	.25	.31	.80	....
	Oxford clay	73	.79	.38	1.88	.21
		34	.21	.38	.81	.55
		60	.91	.34	2.04	.47
		59	.53	.23	.59	.35
		52	.73	.33	1.70	.50
		53	.49	.32	.59	.25
		29	.34	.25	.60	.32
		4	.46	.45	2.99	.38

[a] In the original paper the results are expressed as lime carbonate and lime other than carbonate and have been recalculated to give CaO content. Fifth annual Report on the Soils of Dorset, University College, Reading, 1903

Chemical composition of the soils of Great Britain and Ireland—Continued.

ENGLAND—Continued.

County.	Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Dorset	Cornbrash	10	0.26	0.49	3.16	0.64
		76	.50	.45	6.29	.22
		28	.22	29	6.88	.46
	Fullers earth	18	.41	.45	.99	1.06
		23	.17	.26	.77	.57
		56	.66	.27	.91	.35
		46	.89	.30	1.09	.53
		90	.80	.31	4.50	.53
		26	.53	.17	8.23	1.01
	Inferior oolite	91	.52	.64	4.80	.93
		13	.50	.37	11.60	.29
	Junction inferior oolite and Midford sands.	14	.31	.34	2.44	.60
	Midford sands	55	.38	.36	.77	.48
		54	.38	.25	.45	.44
		45	.44	.38	.58	.41
		5	.33	.49	.31	.39
		92	.26	.60	.42	.29
	Junction Midford sands and marlstone.	6	.21	.31	1.34	.41
		43	.57	.32	1.39	.10
	Marlstone	7	.36	.49	.59	.38
		70	.30	.63	.65	.02
		75	.76	.33	.80	.43
		78	.58	.47	2.44	.61
	Junction marlstone and lower Lias.	24	.27	.29	.72	.38
		44	.69	.35	.95	.39
	Lower Lias	17	.32	.40	2.28	.16
		74	.65	.51	1.14	.84
		93	.51	.53	.96	.55
Essex [a]	Birch		.38	.10	.57	
	Buloau		.38	.10	.83	
	Burnham		.17	.18	1.78	
	Hedingham		.53	.16	1.18	
	Gosfield		.14	{ .14 .24 }	.63	
	Orsett		.12	.08	.36	
	Ramsden		.15	.22	.92	
	Roxwell		.79	.20	5.95	
	Saffron Walden		.34	.11	3.85	
			.41	.10	5.80	
			.48	.09	7.75	
	Tendring		.20	.16	.29	
	Thaxted		.18	.13	.85	
	St. Osyth		.16	.09	1.63	
	Yeldham		.52	.15	1.64	
Cambridge [b]	Hatley plot	3	.85	.39	.88	
	Joint rotation		.64	.22	.90	
	Burgoynes (Univ. farm):					
	Fields 11-13		.625	.083	2.20	
	Fields 14-15		.559	.139	2.15	
	Fields 16-17		.58	.22	.76	
	Fields 18-19		.575	.091	.90	
	Bowlder clay:					
	Above Gault		.948	.14	3.95	.285
	Above Green sand		.785	.113	.78	.28
	Above Gault		.994	.107	1.22	.35
	Above Grey chalk		.963	.102	1.325	.60
	Gault soils		1.14	.14	3.87	.29
			1.143	.127	7.28	.15
			1.13	.097	4.74	.215
	Kimeridge clay soils		1.13	.147	.425	.134
			1.00	.098	.515	.18
			1.58	.093	2.425	.155
	Ampthill clay soils		.655	.096	.48	.145

[a] Dymond, The Essex Field Experiments, 1896-1901, Part I. Compiled for the Essex Technical Instruction Committee.
Jour. Essex Tech. Laboratories, 3, 163 (1897).
Dymond and Bull, the Essex Field Experiments, 1896-1903, No. 2.
Dyer and Rosling, Rep. Field Expts., 1893-4, Essex Agricultural Society.
Guide to Experiments at Univ. Farm and other Centers in the Eastern Counties, Cambridge University, 1907.

[b] Guide to Experiments at University Farm and other Centers in the Eastern counties, Cambridge University, 1907.
Foreman, Journal Agricultural Science, 2, 161 (1907).

Chemical composition of the soils of Great Britain and Ireland—Continued.

ENGLAND—Continued.

County.	Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime. (CaO).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cambridge	Oxford clay soils		1.06	0.118	0.323	0.215
			1.11	.145	.322	.47
			1.09	.138	.308	.25
	Lower green sand soils		.236	.204	.065	.08
			.278	.259	.085	.125
			.47	.197	.34	.24
			.443	.169	.26	.17
			.47	.146	.15	.14
Lincolnshire [a]	Peaty matter from the fens			.25	2.23	
	Fen soil	I	.42	.26	1.44	.28
		II	.43	.21	1.50	.34
		III	.28	.16	1.02	.42
	Marsh soil	I	.16	.16	2.16	.40
		II	.20	.21	2.12	.28
	Farm near Crowland	I	.08	.77	1.20	.30
		II	.07	1.02	1.00	.50
		III	.08	1.24	.87	.13
		IV	.11	1.20	1.24	.21
		V	.08	.68	1.09	.39
		VI	.09	1.23	2.00	.40
Northumberland [b]	Wemonsti Farm plot	1	.283	.106	.306	
		9	.244	.087	.265	
	Miniature Farms	1	.04	.12		
		2	.04	.11		
		3	.04	.13		
		4	.05	.13		
		5	.04	.13		
		6	.05	.12		
	Hanging Leaves		.49	.06	.43	
	Castle Steads		.31	.07	.25	
	Davy Houses		.20	.08	.27	
	East Tower Hill		.06	.17		
	Peepy		{ .144 .114 }	.034	.48	
	Whitefield		.072	.115	.45	
	Kimblesworth		.27	.07	.33	
	Rose Bank		.33	.05	.28	
	Cockle Park:					
	Tower Hill		.80	.04	.31	
	Back House		.263	.097	.286	
	Tree Field		.50	.07	.69	
	Pallace Leas Field plot	1	.36	.10	.44	
		2	.40	.08	.44	
		6	.33	.06	.39	
		8	.28	.06	.37	
		12	.39	.06	.55	
		13	.30	.05	.42	
Northampton [c]	Cransley plot	1	.54	.116	.60	
		2	.57	.145	.67	
		3	.59	.08	.53	
		4	.66	.155	.62	
		5	.50	.139	.45	
		6	.54	.133	.58	
		7	.49	.142	.79	
		8	.50	.113	.45	
		9	.65	.112	.84	
		10	.65	.122	.76	
Isle of Ely [d]	Black soils:					
	White Fen Benwick		.604	.306	2.95	
	Little Port Fen		.559	.284	4.39	
	Wryde		.458	.432	2.54	
	Loam, Wisbeck Fen		.602	.383	3.54	
	Clays, Wryde		.532	.264	.764	
			1.276	.374	1.48	
	Silts, Wryde		.392	.224	3.19	

[a] E. W. Bell, Chemical News, 68, 191 (1893), used HCl (S. G. 1.16).
R. H. Wilson, Chemical News, 70, 153 (1894).
[b] Somerville Agricultural Experiments, 5 years' work at the Northumberland County Demonstration Farm, 1902, pp. 62 and 167.
Gilchrist, Bulletin 4, Armstrong College, Newcastle upon Tyne.
Ninth Annual Report on Experiments, Counties of Cumberland, Durham, and Northumberland, 1900.
Gilchrist, Bulletin 8, County Agricultural Experiment Station, Newcastle upon Tyne.
[c] Report on Experiments at Cransley, Northamptonshire in Seasons 1901, 1902, and 1903, Cambridge University.
[d] First Annual Report of Experiments, 1897, Cambridge, and Counties Agricultural Education Scheme.
Guide to Experiments at University Farm and other Centers in the Eastern Counties, Cambridge, 1907.

Chemical composition of the soils of Great Britain and Ireland—Continued.

ENGLAND—Continued.

County.	Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Isle of Ely	Silts, Needham		0.281	0.245	1.58	
			.288	.192	1.57	
Cheshire [a]		1	.30	.10	.54	
		2	.41	.30	.60	
Norfolk [b]	Saxlingham		.09	.082	.47	
	Stanhoe		.112	.057	1.39	
	Trowse plot	3	.13	.16	1.43	
Suffolk [c]	Bramford		.19	.18	2.18	0.27
	Saxmundham		.71	.248	1.59	
Durham [d]	Grange Hill plot	10	.07	.13		
	Shield Ash plot	1	.35	.09	.54	
		11	.47	.13	.81	
Cumberland [e]	Rose bank plot	1	.37	.05	.27	
		11	.33	.05	.28	
		24	.30	.05	.25	
Hampshire [f]	Newlands Manor, Lymington.		.26	.17	.70	.46
	West Mark, near Petersfield.		.16	.145	.84	.29
Oxford [f]	Wick. Farm:					
	Headington, I		.049	Trace.	.45	.03
	Headington, II		.12	Trace.	5.49	.19
Berkshire [f]	Sutton's seed trial grounds, Reading.		.17	.37	.80	.10
					$CaCO_3$	
Wiltshire [g]	Christchurch, Allotment Station, Warminster.		.38	.34	4.17	.27
	Borham road, Warminster		.369	.258	.195	.21
			.31	.30	.165	.29
	Hormingsham		.366	.254	.125	.18
	Heytesbury		.42	.45	55.36	.13
	Codford allotment soil		.179	.466	12.21	
	Chitterine allotment soils		.246	.908	47.50	
	Imber allotment	1	.154	.370	42.35	
		2	.259	.402	49.97	
	Corsley plot		.459	.134	.60	
	Clay soil, Warminster		.184	.255	25.55	
	York warp soil		.308	.223	4.17	
Kent [h]	London clay:					
	Whilstable		1.13	.119	.35	2.02
	Sheppey		1.44	.111	.224	1.24
	Chalk soils:					
	Wye		.345	.143	7.91	.193
	Minster, Thanet		.478	.101	1.96	.58
			.459	.094	3.70	.04
	Sutton-by-Dover		.432	.192	18.1	.09
	Neophan		.59	.126	12.2	.62
	Wye Court			.244	31.4	
				.151	14.84	
	Wye S. E. A. C.			.194	33.4	
	Olantigh			.180	37.7	
	Wye			.177	28.6	
	Charing		.623	.217	30.9	
	East Lenham		.64	.109	14.2	
	Charing		.479	.132	.44	
			1.07	.136	.99	
	Gault soils:					
	Brook		.899	.133	2.52	.040
			.901	.253	.019	.072
	Westwell		.739	.084	.061	
				.048	2.42	
	Charing			.038	.20	

[a] Yearbook College of Agriculture and Horticulture, Holmes Chapel, Cheshire, 1904.
[b] Guide to Experiments at University Farm and other Centers in the Eastern Counties, Cambridge University, 1907.
[c] Report on Experiments at Bramford and Saxmundham.
[d] Sixth Annual Report on Experiments in Counties of Cumberland, Durham, and Northumberland, 1897.
Tenth Annual Report on Experiments in Counties of Cumberland, Durham, and Northumberland, 1901.
[e] Tenth Annual Report on Experiments in Cumberland, Durham, and Northumberland.
[f] Gilchrist and Foulkes, Suppl. I, Jour. Extension College, Reading, 1896.
[g] Report on Experiments, Wilts County Council, 1892, 1893, 1895.
[h] Hall and Plyman, First Report on Chemical and Physical Study of the Soils of Kent and Surrey, 1902.

Chemical composition of the soils of Great Britain and Ireland—Continued.

ENGLAND—Continued.

County.	Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime. (CaO).	Magnesia (MgO).
Kent	Gault soils:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
	East Lenham	....	0.837	0.12	013.2	....
	Brook	....	.915	.16	.022	....
			1.01	.131	1.76	....
	East Lenham	....	.64	.199	10.6	....
	Hothfield	....	.515	.132	.85	....
Surrey[a]	London clay:					
	Wanborough Station	....	.329	.065	.65	.35
	Ashtead Common	....	.76	.093	.002	1.12
	Wyke	....	.36	.061	.24	....
	Flexford	....	.478	.066	2.4	....
	Stoughton	....	....	.053	.057	....
	Wanborough	....	.493	.078	.03	....
	Raynes Park	....	.67	.097	.073	....
	Horsley	....	.45	.116	.19	....
	Chalk soils:					
	Seale	....	0.236	0.18	56.9	0.40
	Fetcham	....	.298	.193	39.0	2.81
	Puttenham	....	....	.166	53.6	....
	Wanhorough	....	....	.163	61.4	....
	Sutton	....	.265	.138	6.98	....
	Gault soils, Alderholt	....	.068	.092	.040	.009
			....	.151	.025	....
			....	.074	.039	....
			.394	.0895	.024	....

WALES.[b]

					CaO.	
	Garden soil	....	0.142	0.306	1.40	0.671

SCOTLAND.[c]

				$CaCO_3$.	
	Cleghorn, near Lanark, plots 1	0.187	0.104	0.44	....
	2	.116	.126	.32	....
				CaO.	
	Drumford, Helensburgh	.237	.45	0.168	....
	Easterboard, Croy	.213	.128	.403	....
	Birgidale Knock, Rothesay	.928	.244	.638	....
	Tarves	.539	.481	.594	....
	Wester Fintray, Kintore	.244	.283	.593	....
	Fedderate, Maud	.247	.367	.568	....
	Telloch, Lumphanan	.279	.113	.826	....
	Fasque, Fettercairn	.463	.214	.759	....

IRELAND.[d]

Cork	Limestone soils, Shanagany	0.464	0.148	3.938	....
	Old red sandstone, Killeagh	.547	.156	.201	....
Wexford	Silurian clay slate soils:				
	Bally Carney	.384	.156	.268	....
	Clonroche	.720	.167	.301	....
Tipperary	Limestone soils:				
	Rockford	.846	.16	1.568	....
	St. Kieran's	.943	.13	1.266	....

[a] Hall and Plyman, First Report on Chemical and Physical Study of the Soils of Kent and Surrey, 1902.
[b] Annual Report Field Experiments, University College of Wales.
[c] Reports on Experiments, 1893, Glasgow and West of Scotland Technical College.
Reports on Experiments, 1895, Glasgow and West of Scotland Technical College.
Reports on Experiments, 1903 and 1904, Aberdeen and North of Scotland College of Agriculture.
[d] H. C. Sheringham. 1st Annual Report of Field Experiments in Counties of Wexford, Cork, Tipperary, Mayo, Meath, King's and Queen's, 1899.

Chemical composition of the soils of France.

AISNE.[a]

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Semilly	1	0.36	0.09	11.22	0.007
	4	.60	.11	5.07	.003
	6	.22	.07	.52	.004
Chamhry	1	.29	.18	5.44	.004
	3	.21	.09	7.45	.01
	5	.27	.13	34.12	.01
	7	.28	.14	15.55	.004
	8	.08	.03	.92	.005
	10	.28	.06	.86	.005
Bugy-les-Cerny	1	.44	.16	1.76	.01
	3	.41	.07	3.36	.005
	5	.57	.06	1.22	.01
Crepy-en-Laon-nois	1	.28	.06	.96	.05
	3	.08	.02	2.83	.02
	7	.22	.07	34.53	.01
	9	.16	.06	.60	.01
	11	.24	.08	.32	.005
	14	.25	.10	2.40	.01
	16	.19	.12	7.64	.01
	17	.27	.10	58	.01
Vorges	1	.20	.24	5.56	.01
	3	.20	.08	1.04	.005
	5	.22	.08	.60	.01
	7	.33	.10	1.98	.004
	8	.06	.06	59.50	.01
	9	.48	.08	9.36	.01
Presles	1	.38	.06	3.71	.03
	3	.12	.04	3.52	.005
	5	.30	.05	.15	.005
Montherault	1	.37	.08	64.75	.02
	3	.20	.06	2.43	.01
	5	.47	.10	1.10	.06
	8	.07	.04	.18	.005
	11	.42	.11	10.40	.16
	13	.32	.05	4.69	.005
	15	.29	.08	.71	.04
Chevregny	1	.16	.02	.64	.02
	3	.47	.07	2.24	.02
	5	.16	.08	.64	.01
	7	.28	.07	.96	.01
	8	.26	.03	29.20	.01
	9	.21	.07	7.80	.004
	11	.52	.03	.76	.01
	13	.70	.26	7.08	.02
	15	.71	.10	37.00	.005
Urcel	1	.10	.03	.09	.01
	3	.22	.09	4.64	.18
	6	.25	.05	.17	.003
	7	.30	.09	1.12	.015
	9	.12	.04	31.31	.005
Quincy-Basse	1	.10	.08	1.08	.005
	3	.26	.07	2.68	.05
	5	.16	.08	.88	.02
Landricourt	1	.10	.08	1.08	.005
	3	.26	.07	2.68	.05
	6	.30	.08	.48	.02
	8	.30	.08	.92	.01
	10	.39	.10	1.72	.02
Jumencourt	1	.18	.08	9.20	.006
	2	.57	.08	.76	.27
	4	.18	.08	39.70	.01
Folembray	1	.25	.03	1.60	.01
	3	.12	.04	.08	.02
	5	.22	.03	2.93	.08
	7	.15	.03	.32	.003
	8	.11	.04	1.70	.02
	10	.15	.05	.50	.01
Leuilly-sous Coucy	1	.22	.09	1.76	.006
	3	.24	.10	2.00	.003
	4	.26	.06	.52	.005
	7	.23	.05	.37	.003
Crecy-au-Mont	1	.23	.12	4.94	.01
	3	.27	.07	.28	.01
	5	.29	.11	.68	.02

[a] Bulletins Sta. Agron. Dep. de l'Aisne, 1891, 1892, 1893, 1894.

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5)	Lime ($CaCO_3$)	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crecy-au-Mont	7	0.25	0.08	0.64	0.39
	9	.19	.06	51.20	.01
	11	.47	.09	7.98	.01
	13	.50	.07	.72	.02
	15	.15	.04	2.39	.01
Pont-Saint Mard	1	.18	.06	.24	.006
	3	.25	.08	.52	.006
	5	.26	.08	32.30	.03
	7	.30	.03	.17	.006
	9	.26	.06	.84	.005
Vaudesson	3	.17	.06	.72	.02
	5	.21	.08	17.08	.01
	6	.38	.10	.18	.02
	8	.19	.06	.41	.01
	10	.33	.08	.18	.004
	12	.25	.05	1.00	.47
Couvrelles	1	.55	.13	2.12	.006
	5	.18	.02	81.20	.006
	7	.27	.06	.40	.006
	9	.39	.03	3.23	.005
	11	.26	.04	.15	.02
	13	.38	.09	.79	.07
	15	.31	.09	.86	.06
Mercin	1	.20	.09	.72	.01
	3	.22	.11	.73	.01
	7	.28	.06	1.00	.01
	9	.23	.04	.36	.004
	11	.22	.04	3.14	.04
	13	.08	.13	.55	.01
Amifontaine	1	.24	.24	7.08	.004
	3	.19	.15	13.21	.005
	4	.13	.09	10.60	007
	5	.39	.19	33.92	.006
	6	.15	.19	10.48	.005
	7	.45	.13	33.70	.006
	8	.18	.06	9.34	.01
	10	.29	.16	63.80	.007
	11	.26	.09	14.40	.007
Juvincourt	1	.23	.09	13.12	.005
	2	.14	.07	1.34	.01
	4	.28	.11	35.50	12
Berry-au-Bac	1	.37	.16	49.20	.03
	2	.32	.21	25.00	.03
	4	.30	.12	23.60	.04
Gernicourt	1	.29	.10	4.82	.01
	2	.09	.02	.68	.005
	4	.14	.03	9.90	.006
	6	.27	27	30.70	.06
	7	.17	.07	75.90	.01
Clermont-les-Fermes	1	.25	.10	.57	.02
	3	.37	17	6.00	.01
	5	.20	.11	1.28	.003
	7	.30	.12	2.19	.002
	9	.31	.08	.98	.003
	11	.35	.10	45	003
	13	.25	.08	36	.04
	15	.21	.08	16	005
	17	.43	.10	.80	.004
Missy-les-Pierrepont	1	19	.06	.29	.006
	3	.27	.15	2.24	.008
	4	.40	.07	2.66	.07
	6	.29	.06	.38	03
	8	.28	.09	.70	02
Grandlup	1	.35	.13	0.94	01
	2	.21	.08	2.20	01
	3	.24	.06	.28	01
	5	.40	.14	1.63	01
	7	38	.14	3.08	01
	8	.15	.09	1.63	.01
Frieres-Faillouel	1	19	.08	1.70	.006
	3	29	.09	5.16	.01
	5	30	.07	.38	.10
	9	.35	.09	5.46	.005
	10	.33	.07	2.32	.01

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Liez	1	0.25	0.11	3.06	0.005
	4	.32	.07	5.24	.01
	6	.22	.08	3.18	.004
	8	.18	.11	39.50	.01
	10	.20	.11	1.05	.005
	12	.18	.20	.36	.01
	14	.24	.08	1.33	.01
Charmes	1	.47	.11	.58	.003
	3	.25	.07	2.62	.02
	5	.58	.13	5.28	.004
	7	.15	.09	1.56	.004
	9	.27	.09	1.60	.01
	12	.85	.12	7.04	.01
Rogecourt	1	.28	.10	3.08	.05
	3	.13	.08	2.03	.07
	5	.24	.08	3.14	.01
	8	.28	.09	1.13	.006
	9	.23	.04	3.68	.02
Fressancourt	1	.28	.08	.52	.02
	3	.29	.08	1.96	.05
	5	.26	.10	2.32	.008
	7	.28	.10	5.84	.005
Faucouzy	1	.31	.10	4.50	.04
	4	.37	.15	3.40	.05
	5	.32	.20	65.50	.003
	6	.34	.09	.72	.04
	8	.60	.18	28.80	.004
	10	.22	.11	2.40	.08
	12	.30	.14	19.70	.02
	14	.35	.87	62.00	.01
Chevresis-Monceau	1	.28	.10	5.10	.01
	3	.22	.10	33.88	.005
	5	.08	.05	35.08	.01
	7	.25	.10	15.65	.004
	9	.05	.10	48.30	.004
Grugies	1	.34	.08	.25	.01
	4	.35	.14	4.76	.01
	6	.45	.06	8.22	.005
	8	.27	.04	41.44	.005
	9	.24	.08	.46	.005
Crezancy	1	.20	.06	34.20	.02
	5	.29	.03	.54	.01
	7	.47	.10	8.26	.02
	11	.33	.09	10.20	.01
Epieds	1	.21	.07	1.15	.006
	3	.26	.06	.28	.01
	6	.27	.06	.78	.02
	9	.48	.07	16.98	.01
	11	.21	.06	.68	.02
	13	.19	.05	1.50	.02
Torcy	1	.19	.05	.68	.006
	3	.09	.04	1.28	.006
	5	.18	.06	8.91	.04
	7	.26	.08	3.30	.03
	9	.20	.05	.61	.01
	11	.35	.05	.98	.02
Pouilly-sur-Serre	1	.23	.15	2.19	.004
	3	.35	.04	.45	.003
	5	.25	.04	5.24	.005
	7	.32	.04	.34	.005
	9	.30	.23	8.00	.004
	10	.30	.06	33.93	.005
	13	.65	.05	3.25	.003
Mouvion et Catillon	1	.33	.03	.80	.005
	3	.39	.10	.50	.003
	5	.43	.05	1.70	.01
	6	.42	.11	1.42	.005
	8	.30	.08	.48	.006
	10	.30	.09	.70	.005
	12	.37	.07	1.28	.01
	13	.35	.07	.48	.01
	15	.24	.12	53.20	.005
Mesbrecourt-Richecourt	1	.35	.11	4.20	.006
	3	.37	.14	.38	.003

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Mesbrecourt-Richecourt	5	0.58	0.08	0.39	0.01
	7	.32	.13	1.18	.01
	9	.26	.11	49.00	.01
	10	.46	.05	1.30	.006
	12	.44	.11	1.24	.01
	14	.51	.10	.39	.01
	16	.27	.12	1.16	.006
La Ferte-Chevresis	1	.34	.08	2.58	.01
	3	.46	.11	1.16	.01
	5	.38	.13	.74	.01
	7	.30	.11	28.44	.004
	8	.37	.19	45.16	.01
	9	.31	.12	1.95	.005
	11	.69	.16	.67	.006
	13	.32	.11	9.98	.01
Valecourt	1	.33	.20	56.45	.005
	2	.57	.06	2.60	.006
	5	.39	.07	3.94	.01
	7	.37	.10	.66	.01
	10	.32	.08	36.80	.01
	11	.37	.09	1.24	.01
Pargny-les-Bois	1	.32	.04	.30	.01
	3	.13	.13	62.00	.01
	6	.42	.10	1.06	.01
Bois-les-Pargny	1	.33	.05	.28	.05
	3	.48	.08	.84	.004
	5	.21	.09	.38	.01
	7	.34	.07	.64	.01
Erlon	1	.14	.08	1.36	.01
	3	.29	.08	.52	.01
	5	.28	.09	.46	.002
	7	.30	.07	.37	.01
	9	.24	.05	.70	.02
	11	.15	.14	62.45	.04
Marcy	1	.20	.04	.32	.003
	3	.30	.15	37.00	.003
	5	.36	.12	.60	.10
	7	.27	.08	.41	.006
Vayenne	1	.23	.08	.68	.01
	3	.37	.13	.18	.01
	5	.31	.12	7.88	.01
	7	.27	.14	15.53	.01
	9	.28	.18	7.96	.01
Marle	1	.42	.16	.85	.006
	3	.31	.07	1.00	.01
	5	.41	.09	.70	.02
	7	.23	.07	.80	.02
	9	.47	.14	.80	.01
Houry	1	.42	.09	1.18	.01
	3	.50	.18	1.44	.01
	6	.27	.10	1.65	.02
	8	.48	.13	2.96	.01
	10	.35	.09	4.78	.01
Prisces	1	.61	.15	.76	.006
	3	.30	.16	1.47	.005
	5	.53	.23	.64	.007
	7	.34	.13	1.30	.006
	9	1.30	.80	.70	.006
Gronard	1	.33	.08	1.04	.03
	4	.26	.07	.56	.003
	6	.28	.03	1.84	.005
Agnicourt et Sechelles	1	.28	.11	3.00	.02
	3	.28	.26	8.08	.01
	5	.30	.10	1.18	.01
	7	.26	.18	2.55	.01
	9	.25	.25	53.50	.02
	10	.51	.15	.68	.01
	12	.30	.10	.32	.01
	14	.21	.17	87.00	.01
Montloue	1	.23	.07	.32	.01
	3	.28	.09	.68	.01
	5	.45	.08	.78	.01
	7	.21	.15	56.00	.02
	9	.35	.17	1.68	.04

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Noircourt	1	0.43	0.06	5.88	0.01
	3	.50	.08	.36	.006
	5	.29	.06	3.55	.02
	7	.41	.11	13.50	.003
	11	.15	.16	38.00	.006
	12	.40	.08	.98	.01
	14	.14	.10	1.97	.02
	16	.14	.06	1.36	.03
	18	.35	.05	.48	.01
Goudelancourt	1	.39	.18	26.50	.004
	3	.23	.07	.50	.005
	5	.41	.10	.72	.01
Ebouleau	1	.52	.08	.25	.004
	3	.39	.07	.40	.004
	5	.25	.09	.14	.007
	7	.28	.05	42.00	.007
Bucy-les-Pierrepont	1	.16	.06	.14	.003
	3	.24	.08	29.50	.004
	5	.20	.07	.52	.02
	7	.44	.08	.42	.01
	9	.39	.07	.34	.003
	11	.40	.06	.44	.01
	13	.27	.02	.12	.004
	15	.37	.08	.72	.01
Boncourt	1	.25	.09	.28	.12
	3	.29	.07	.26	.03
	5	.28	.10	.48	.01
	7	.28	.08	.80	.11
Lappion	1	.30	.11	47.00	.02
	3	.14	.04	.22	.01
	5	.23	.04	.12	.02
	6	.26	.05	.28	.02
	8	29	.07	.24	.02
	10	.28	.15	94.70	.19
	13	.37	.04	.64	.03
La Selve	1	.32	.04	1.84	.02
	2	.14	.08	48.00	.007
	3	.26	.07	.78	.02
Sissonne	1	.24	.21	43.00	.005
	3	.33	.07	9.20	.004
	4	.24	.09	.80	.004
	5	.24	.13	23.22	.003
	6	.28	.15	15.64	.007
	7	.30	.50	16.19	.003
	8	.49	.32	10.71	.005
	9	.14	.06	.52	.004
	10	.12	.04	.24	.004
Machecourt	1	.29	.12	49.00	.009
	3	.35	.03	.80	.006
	5	.39	.11	1.40	.002
	7	.44	.06	1.96	.01
Chivres	1	.47	.17	20.00	.004
	3	.24	.14	46.60	.003
	4	.23	.05	.24	.01
	6	.41	.19	5.64	.23
Liesse	1	27	.04	1.63	.004
Gizy	1	.20	.03	.52	.009
	3	.47	.04	.38	.007
	5	.30	.05	.20	.01
	7	.27	.09	.68	.02
Samoussy	1	.37	.06	.24	.008
	4	.27	.14	39.75	.01
	6	.24	.10	2.60	.01
	8	.23	.17	26.00	.02
Manceau-le-Waast	1	.25	.08	2.97	.01
	3	.19	.14	3.25	.03
Athies	1	.38	.12	.52	.01
	2	.40	.06	.28	.01
	4	.23	.09	1.00	.004
	6	.22	.07	.80	.007
	8	.29	.06	14.00	.006
	9	.27	.03	.64	.004
Eppes	1	.31	.09	86.00	.006
	2	.30	.06	8.00	.006

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Coucy-les-Eppes	1	0.16	0.04	0.30	0.005
	3	.45	.08	.42	.004
	5	.19	.07	.36	.01
	6	.21	.03	.30	.001
	8	.47	.17	7.30	.01
	9	.29	.09	35.50	.003
	10	.25	.09	2.10	.003
Festieux	1	.16	.03	.16	.004
	3	.25	.07	10.50	.005
	4	.29	.13	25.44	.006
	5	.50	.08	1.50	.007
Veslud	1	.19	.04	.24	.003
	3	.18	.03	.04	.03
	4	.33	.05	.88	.004
	6	.35	.13	20.00	.01
Parfondru	1	.32	.10	.16	.007
	2	.52	.15	2.88	.01
	5	.26	.05	5.40	.02
Bruyeres	1	.14	.05	.24	.02
Arrancy	1	.32	.07	1.00	.008
	3	.27	.03	.84	.007
	5	.21	.05	10.88	.006
Ployart	1	.24	.11	.63	.007
	3	.44	.06	3.37	.03
	5	.18	.10	2.40	.01
Vaureseine	1	.37	.09	20.00	.007
	3	.33	.06	10.00	.02
	5	.24	.12	.40	.006
Montchalons	1	.40	.16	.60	.008
	3	.32	.10	3.40	.005
	5	.32	.04	.20	.005
Cheret	1	.36	.07	47.00	.02
	2	.36	.07	19.00	.02
Orgeval	1	.25	.06	1.40	.007
	4	.27	.14	.84	.004
Bievres	1	.26	.10	.44	.03
	3	.36	.17	20.00	.01
	4	.28	.10	11.00	.006
Martigny	1	.36	.07	1.10	.007
	3	.33	.07	13.06	.05
	4	.39	.12	13.18	.31
	5	.40	.07	.46	.08
Monampteuil	1	.20	.07	.99	.002
	3	.27	.05	.19	.005
	5	.20	.07	.23	.004
	7	.19	.07	.24	.005
	9	.34	.07	.45	.005
Braisne	1	.23	.67	.50	.03
	3	.28	.06	.48	.02
	5	.20	.05	.84	.02
	7	.17	.12	7.00	.01
Brenelle	1	.35	.04	.48	.01
Courcelles	1	.34	.05	.78	.01
	3	.47	.08	1.66	.03
	5	.24	.08	1.26	.03
	7	.28	.05	65.00	.01
	8	.16	.04	27.00	.01
	10	.20	.07	.44	.01
Lime	1	.32	.05	.74	.02
	3	.23	.05	.26	.01
	5	.31	.07	.42	.01
	7	.64	.07	.70	.01
	9	.32	.91	29.00	.01
Quincy-sous-Le-Mont et Bruyeres	2	.26	.05	.30	.02
	4	.27	.06	.41	.005
	6	.24	.09	.56	.01
	8	.22	.05	.58	.01
Laffaux	1	.24	.05	1.09	.008
	3	.37	.07	1.90	.008
	5	.22	.06	.52	.007
Neuville-sur-Margival	1	.42	.07	.48	.01
	3	.29	.06	.30	.005
Terny-Sorny	1	.36	.06	1.42	.006
	3	.39	.12	21.20	.006
	5	.38	.06	1.22	.003
	7	.26	.06	.42	.004
	9	.30	.07	.72	.02

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Margival	1	0.28	0.06	3.68	0.01
	3	.48	.08	2.02	.01
	5	.28	.08	.82	.005
	7	.28	.05	81.00	.003
	9	.26	.06	3.68	.005
Vuillery et Braye-sous-Clamecy	1	.28	.07	.34	.008
Villemontoire	1	.24	.13	5.10	.02
	3	.29	.09	.72	.01
	5	.16	.07	18.20	.03
	7	.20	.09	.82	.03
	9	.16	.08	.60	.007
Buzancy	1	.27	.04	.98	.01
	3	.33	.06	1.70	.01
	5	.31	.06	.40	.006
	8	.31	.07	3.41	.03
Aconin	1	.33	.08	9.70	.01
	3	.30	.09	1.10	.01
	4	.32	.06	.86	.02
	6	.37	.16	.40	.006
Cutry	1	.3	.05	.10	.005
	3	.38	.07	.24	.01
	5	.66	.07	1.88	.01
	7	.38	.06	.48	.004
Cœuvres et Valsery	1	.38	.08	.20	.01
	3	.24	.06	.24	.006
	5	.26	.07	54.00	.01
	6	.34	.12	2.24	.008
	7	.37	.08	.36	.01
Saint-Pierre-Aigle	1	.29	.03	.48	.007
	3	.25	.07	.24	.01
Laversiene	1	.33	2.02	.28	.005
	3	.31	.08	.28	.01
Dommiers	1	.31	.06	.20	.01
	3	.37	.10	.36	.05
Berny-Riviere	1	.8	.12	41.90	.003
	2	.80	.14	17.00	.003
Nouvron	1	.57	.08	.73	.01
	3	.64	.09	.65	.01
	5	.32	.06	.45	.003
	7	.42	.06	5.09	.02
	8	.14	.01	86.70	.004
Morsain	1	.30	.05	2.16	.007
	2	.18	.07	.70	.005
	3	.22	.06	2.23	.005
	5	.20	.05	5.44	.01
Vezaponin	2	.30	.05	33.04	.01
	4	.50	.03	.50	.01
	6	.44	.05	.30	.01
Selens	1	.29	.28	1.48	.01
	4	.12	.06	44.00	.01
	5	.39	.06	3.00	.03
	8	.35	.08	.61	.01
	10	.26	.04	1.18	.03
Saint-Aubin	1	.26	.06	1.08	.05
	3	.15	.05	2.80	.06
Trosly-Loire	1	.24	.06	2.27	.04
	3	.16	.06	.68	.05
	4	.19	.08	1.52	.06
	5	.17	.07	.82	.06
	7	.22	.03	9.96	.06
	8	.17	.09	2.08	.05
	9	.22	.07	.78	.03
Villequier-Aumont	1	.32	.05	.68	.01
	4	.57	.32	.38	.004
	6	.26	.08	.38	.008
	8	.26	.05	.82	.01
	10	.28	.05	.38	.01
Landouzy-la-Cour	2	.27	.11	2.30	.01
	4	.32	.06	.64	.01
	6	.35	.10	.38	.01
	10	.23	.09	.60	.01
	12	.34	.08	.20	.007
	14	.39	.08	1.00	.006
Vervins	1	.27	.11	.32	.01
	3	.24	.10	.20	.007
	5	.36	.10	1.28	.01
Fontaine-les-Vervins	1	.28	.11	.60	.08
	3	.39	.10	93.00	.007

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Fontaine-les-Vervins	4	0.33	0.10	0.68	0.009
	6	.32	.07	2.20	.006
	8	.40	.10	1.84	.007
Laigny	1	.29	.04	.44	.001
	3	.30	.10	.80	.006
	6	.30	.11	9.44	.01
Haution	1	.31	.08	1.24	.006
	3	.26	.09	.32	.007
Voulpaix	1	.31	.09	.56	.003
	2	.66	.07	.36	.007
	3	.24	.08	1.24	.01
	5	.28	.09	.88	.008
Marfontaine	1	.31	.17	1.96	.01
	2	.24	.06	.36	.01
	4	.28	.09	.52	.004
Rougeries	1	.33	.09	.92	.006
Presles	1	.25	.05	.35	.01
Nouvion	1	.47	.10	1.68	.006
	4	.30	.05	.15	.005
Laval	3	.27	.10	.56	.006
	6	.12	.06	.60	.02
Monthenault	1	.54	.07	.52	.005
	3	.46	.07	.16	.005
	5	.40	.04	.72	.004
	7	.40	.06	.06	.004
	8	.35	.04	1.64	.005
Chamouille	1	.32	.10	2.56	.05
	2	.38	.08	6.60	.006
Courtecon	1	.27	.06	.36	.006
	3	.26	.06	.70	.02
	5	.26	.06	.48	.003
	7	.37	.17	.96	.007
	10	.33	.08	11.30	.03
Pancy	1	.24	.02	.20	.007
	3	.52	.09	.52	.01
Colligis	1	.52	.07	.84	.01
	3	.58	.05	9.96	.007
Grandelain	1	.28	.05	.24	.007
	4	.29	.07	.22	.01
	6	.33	.05	.18	.005
Trucy	1	.36	.07	.28	.003
	3	.33	.03	.20	.004
Lierval	1	.32	.06	19.86	.22
	2	.56	.12	8.52	.01
Lesdins	1	.34	.14	.44	.01
	3	.30	.16	56.40	.004
	5	.39	.08	2.80	.02
	7	.38	.13	1.44	.01
Levergies	1	.27	.10	18.04	.02
	4	.27	.07	2.04	.02
	6	.36	.09	.92	.01
	8	.37	.10	.54	.01
Guoy	1	.39	.07	3.70	.01
	3	.59	.14	.76	.005
	5	.40	.12	.76	.01
	7	.17	.12	42.40	.01
	8	.51	.12	1.08	.006
	10	.50	.10	.60	.01
	12	.51	.09	1.76	.004
	14	.44	.09	11.92	.01
	16	.38	.10	.64	.01
Prouvais	1	.22	.08	.68	.007
	3	.29	.06	2.80	.02
	6	.40	.22	32.70	.01
	7	.21	.24	34.00	.01
	9	.46	.30	52.00	.02
	10	.22	.15	7.44	.01
Molinchart	1	.36	.09	3.40	.01
	3	.27	.04	.32	.005
Clacy	5	.38	.09	44.50	.01
Merlieux	1	.30	.11	6.40	.02
	2	.32	.23	2.06	.03

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Merlieux	3	0.38	0.06	0.16	0.003
	5	.32	.04	.16	.003
Montbavin et Montarsene	1	.37	.07	.62	.01
	3	.26	.05	.76	.01
	5	.19	.04	.40	.01
	7	.23	.04	.12	.01
	8	.28	.05	.22	.01
	9	.20	.08	27.00	.02
Barisis	1	.22	.06	.64	.007
	3	.38	.08	1.00	.004
	6	.23	.06	22.00	.005
	7	.29	.05	1.08	.003
Mont-Saint-Martin	1	.42	.09	6.70	.02
	3	.39	.10	1.04	.007
	5	.36	.09	15.60	.01
	8	.45	.06	.48	.01
Nesles	1	.23	.06	.48	.02
	3	.38	.06	.28	.004
	5	.29	.06	.20	.005
	7	.26	.05	.60	.003
	9	.28	.10	.80	.01
Nogentel	3	.24	.06	32.00	.02
	4	.40	.23	5.80	.01
Etampes	1	.72	.09	1.36	.04
	2	.24	.12	7.50	.005
Chierry	1	.29	.15	15.92	.03
	3	.40	.20	20.00	.01
Fossoy	1	.77	.08	17.46	.03
	3	.17	.12	13.74	.006
	5	.33	.06	14.96	.02
Seraucourt-Le-Grand	1	.28	.14	3.53	.02
	3	.29	.06	.10	.02
	5	.50	.09	1.08	.01
	7	.28	.21	3.24	.007
Happencourt	1	.44	.15	3.23	.008
	3	.42	.22	31.00	.02
	5	.38	.10	8.64	.01
Artemps	1	.47	.13	2.98	.01
	3	.30	.10	1.56	.01
Clastres	1	.32	.05	.60	.005
Guise	1	.29	.08	.20	.02
	4	.64	.11	2.64	.03
	6	.40	.09	.70	.007
	8	.39	.03	.24	.003
Lesquielles-Saint-Germain	1	.27	.56	45.00	.01
	2	.46	.07	.72	.01
	4	.36	.12	3.04	.01
	6	.31	.10	.60	.003
Vieil Arcy	1	.36	.07	1.40	.003
	3	.14	.07	.40	.002
	5	.25	.07	16.00	.002
	7	.14	.10	3.16	.003
	10	.47	.25	13.60	.002
Dhuizel	1	.39	.07	.60	.004
	3	.25	.07	.76	.003
Longpont	1	.65	.16	1.00	.002
	2	.30	.07	.92	.004
	4	.35	.11	1.10	.005
	6	.43	.06	1.00	.004
	9	.34	.09	16.80	.002
Couvron	1	.31	.16	4.06	.04
	3	.34	.12	5.88	.03
	4	.17	.18	58.00	.02
	5	.21	.07	.20	.04
Barenton-Cel	1	.51	.10	2.62	.01
	3	.35	.09	8.70	.02
	4	.39	.09	1.62	.007
	6	.14	.19	72.00	.006
	8	.51	.08	.60	.003
	10	.41	.07	14.00	.009
Chalandry	1	.49	.09	1.80	.004
	3	.32	.12	2.10	.01

Chemical composition of the soils of France—Continued.

AISNE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
LAON—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cessieres	1	0.28	0.12	0.56	0.001
	3	.33	.06	.36	.002
	5	.45	.05	.52	.02
	5	.34	.07	.36	.002
Guivry	2	.27	.07	.40	.003
	4	.24	.08	.48	.004
	8	.33	.09	.72	.004
Berlancourt	1	.38	.08	1.20	.02
	3	.43	.09	2.20	.05
	5	.27	.09	5.50	.01
	7	.23	.11	16.00	.006
	8	.36	.09	2.68	.02
Neuville-Saint Amand	1	.41	.08	.20	.005
	3	.49	.12	2.00	.009
	5	.43	.03	2.16	.005
	7	.45	.16	47.00	.007
	8	.33	.07	3.02	.006
	10	.35	.07	1.40	.006
	12	.40	.09	1.60	.006
	15	.53	.18	1.00	.005
Remaucourt	1	.38	.16	3.36	.01
	3	.47	.13	1.62	.01
	6	.37	.12	2.52	.01
	9	.34	.22	39.50	.01
Vauxresis	1	.34	.07	.64	.002
Cuisy en Almont	1	.41	.09	.24	.004
	3	.31	.07	1.08	.002

PAS-DE-CALAIS.[a]

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
Erquieres	1	0.268	0.119	0.405	....
	2	.137	.092	2.411	....
	3	.267	.098	1.836	....
	4	.267	.103	3.875	....
	5	.298	.211	15.565	....
	6	.219	.172	57.344	....
Guigny	1	.32	.143	1.652	....
	2	.35	.086	1.932	....
	3	.30	.104	1.897	....
	4	.289	.159	8.112	....
	5	.317	.121	35.971	....
Berthonval	1	.26	.10	1.17	....
	2	.33	.14	1.51	....
	3	.30	.115	.20	....
	4	.29	.22	23.39	....
	5	.34	.094	.925	....
Louez	1	.316	.116	.70	....
	2	.293	.118	1.20	....
	3	.388	.158	4.215	....
	4	.333	.19	4.265	....
	5	.319	.26	23.00	....
	6	.328	.252	23.00	....
Valhuon	1	.376	.096	1.12	....
	2	.314	.094	.716	....
	3	.245	.092	1.36	....
	4	.219	.094	1.05	....
	5	.266	.084	1.19	....
Saint Martin	1	.121	.108	.135	....
	2	.176	.156	1.085	....
	3	.154	.15	.625	....
	4	.176	.156	2.70	....
	5	.169	.146	.475	....
	6	.185	.156	1.35	....
	1	.191	.159	.533	....
	2	.198	.133	4.906	....
	3	.249	.121	1.183	....
	4	.248	.145	2.786	....
	5	.289	.158	1.848	....
	6	.30	.086	.648	....
	7	.198	.142	1.041	....
	8	.174	.098	1.041	....

[a] Terres Arables de Pas-de-Calais, Pagnoul, 1894. Bulletin Station Agronomique Pas-de-Calais, 1895.

Chemical composition of the soils of France—Continued.

PAS-DE-CALAIS—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Marck	1	0.33	0.116	18.011	....
	2	.256	.063	14.016	....
	3	.347	.129	25.145	....
	4	.25	.092	22.086	....
	5	.043	.031	.101	....
	6	.25	.116	14.974	....
Offekerque	1	.384	.104	16.412	....
	2	.29	.101	14.101	....
	3	.22	.092	13.834	....
	4	.291	.105	15.806	....
Guines	1	.235	.153	.96	....
	2	.282	.167	7.699	....
	3	.248	.254	21.334	....
	4	.324	.224	13.014	....
Faubourg Ronville	1	.26	.704	38.75	....
	2	.223	.704	34.427	....
	3	.257	.554	19.739	....
	4	.295	.40	4.572	....
	5	.258	.194	1.625	....
	6	.266	.642	9.639	....
Souastre	1	.268	.092	1.84	....
	2	.241	.091	1.47	....
	3	.277	.11	.518	....
	4	.267	.075	1.504	....
	5	.239	.09	2.053	....
	6	.29	.08	2.21	....
	7	.249	.092	2.596	....
Pas	1	.262	.08	1.02	....
	2	.208	.134	3.866	....
	3	.311	.081	3.112	....
	4	.345	.08	.97	....
	5	.245	.28	.923	....
	6	.256	.056	.031	....
	7	.177	.25	62.448	....
	8	.199	.104	1.62	....
	9	.31	.10	2.72	....
Serres	1	.278	.123	.961	....
	2	.122	.143	.468	....
	3	.30	.118	4.17	....
	4	.255	.106	.75	....
	5	.315	.114	1.62	....
	6	.263	.107	2.02	....
	7	.268	.11	1.11	....
Fresnes-lez-Montauban	1	.277	.162	35.272	....
	2	.36	.11	1.972	....
	3	.257	.085	1.901	....
	4	.323	.11	1.633	....
	5	.292	.231	42.112	....
Adinfer	1	.367	.114	1.14	....
	2	.337	.10	.861	....
	3	.307	.094	.526	....
	4	.262	.093	.774	....
	5	.286	.103	2.402	....
	6	.30	.106	1.208	....
	7	.288	.084	.125	....
	8	.253	.071	.077	....
Henin-sur-Cojeul	1	.289	.186	14.40	....
	2	.228	.115	2.53	....
	3	.262	.123	2.30	....
	4	.313	.096	1.15	....
	5	.268	.163	10.42	....
	6	.313	.094	.93	....
Achicourt	1	.277	.571	7.173	....
	2	.263	.292	7.698	....
	3	.278	.16	1.901	....
	4	.329	.149	1.288	....
	5	.295	.159	2.263	....
	6	.257	.57	35.968	....
	7	.278	.57	32.988	....
	8	.355	.14	2.68	....
	9	.317	.329	4.67	....
Croisilles	1	.334	.109	2.061	....
	2	.286	.108	.592	....
	3	.308	.114	.992	....
	4	.305	.103	1.511	....
	5	.265	.114	12.525	....

Chemical composition of the soils of France—Continued.

PAS-DE-CALAIS—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Croisilles	6	0.325	0.125	1.003	...
	7	.26	.157	16.67	...
	8	.282	.093	.459	...
La Herliere	1	.275	.075	2.917	...
	2	.273	.066	3.00	...
	3	.276	.08	1.904	...
	4	.249	.099	4.857	...
	5	.276	.089	2.145	...
Moyenneville	1	.309	.102	.614	...
	2	.317	.091	.208	...
Moyenneville	3	.317	.107	.774	...
	4	.306	.099	.811	...
	5	.215	.103	.381	...
	6	.345	.133	.684	...
Ablainzevelle	1	.316	.102	.603	...
	2	.162	.114	.59	...
	3	.304	.092	.359	...
	4	.266	.072	.251	...
	5	.269	.071	1.53	...
	6	.292	.102	.429	...
	7	.224	.073	1.845	...
	8	.25	.071	.102	...
	9	.269	.085	2.052	...
	10	.255	.081	.28	...
Havrincourt	1	.272	.111	1.537	...
	2	.237	.097	.799	...
	3	.283	.137	3.646	...
	4	.319	.103	.605	...
	5	.237	.124	3.469	...
	6	.399	.128	1.652	...
	7	.275	.09	.62	...
	8	.337	.159	.87	...
	9	.35	.106	.848	...
	10	.341	.122	2.628	...
	11	.25	.103	1.578	...
	12	.206	.27	39.918	...
Hesdignaul	1	.248	.081	.573	...
	2	.276	.087	.57	...
	3	.257	.139	.877	...
	4	.337	.116	1.687	...
	5	.268	.067	.245	...
	6	.205	.074	1.171	...
	7	.264	.073	.051	...
	8	.266	.072	.243	...
	9	.182	.095	.255	...
	10	.322	.126	1.413	...
Metz-en-Couture	1	.272	.116	2.536	...
	2	.228	.111	.93	...
	3	.227	.133	1.734	...
	4	.239	.107	.568	...
	5	.323	.131	.758	...
	6	.233	.105	.711	...
	7	.289	.118	2.344	...
	8	.218	.15	.876	...
	9	.218	.098	1.996	...
	10	.243	.105	.537	...
	11	.22	.103	2.599	...
Fontaine-les-Boulans	1	.308	.096	1.884	...
	2	.38	.314	11.117	...
	3	.365	.083	65.90	...
	4	.297	.073	3.899	...
	5	.503	.39	14.713	...
	6	.545	.422	30.198	...
Clairmarais	1	.253	.054	2.171	...
	2	.414	.088	.675	...
	3	.284	.07	1.514	...
	4	.26	.069	.902	...
	5	.36	.081	1.022	...
	6	.378	.26	33.837	...
	7	.31	.078	2.12	...
	8	.31	.142	16.783	...
	9	.53	.10	3.685	...
Wizernes	1	.249	.074	.253	...
	2	.379	.063	1.059	...
	3	.271	.06	1.33	...
Racquinghem	1	.385	.072	.00	...
	2	.31	.093	.671	...
	3	.28	.099	.774	...
	4	.266	.086	1.224	...

Chemical composition of the soils of France—Continued.

PAS-DE-CALAIS—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Racquinghem	5	0.353	0 114	1.237	....
	6	.282	.039	1.003	....
	7	.557	.045	.929	....
	8	.761	.038	.608	....
	9	.178	.00	.00	....
Houlle	1	.232	.085	2.204	....
	2	.245	.161	28.211	....
	3	.279	.105	4.167	....
	4	.21	.111	2.648	....
	5	.178	.102	3.439	....
Moulle	1	.217	.082	2.203	....
	2	.171	.088	1.463	....
	3	.279	.105	4.167	....
	4	.21	.111	2.648	....
	5	.178	.102	3.439	....
Zoteux	1	.201	.126	2.08	....
	2	.293	.117	.436	....
	3	.287	.223	6.007	....
	4	.395	.209	1.807	....
	5	.196	.104	.212	....
	6	.272	.193	4.813	....
Mentque-Northecourt	1	.144	.162	61.819	....
	2	.292	.141	12.013	....
	3	.196	.141	6.114	....
	4	.297	.159	7.612	....
	5	.197	.151	39.253	....
	6	.266	.133	11.502	....
Isques	1	.404	.176	7.955	....
	2	.314	.139	1.005	....
	3	.199	.073	2.163	....
	4	.236	.092	.174	....
	5	.234	.09	.242	....
	6	.466	.257	9.746	....
Hubersent	1	.358	.248	8.238	....
	2	.147	.136	32.749	....
	3	.202	.093	3.213	....
	4	.272	.079	.328	....
	5	.211	.084	2.803	....
	6	.20	.071	.092	....
Bailleul-les-Pernes	1	.357	.066	23.731	....
	2	.243	.079	.796	....
	3	.301	.083	1.466	....
	4	.214	.065	1.247	....
	5	.287	.121	.873	....
	6	.30	.175	6.479	....
Auchy-lez-Hesdin	1	.195	.124	3.594	....
	2	.224	.091	.332	....
	3	.27	.119	.694	....
Rang-du-Fliers	1	.23	.057	18.422	....
	2	.135	.086	2.065	....
	3	.225	.277	17.465	....
	4	.219	.061	21.053	....
	5	.208	.051	17.912	....
	6	.143	.083	14.489	....
Labourse	1	.40	.219	25.177	....
	2	.325	.225	23.305	....
	3	.281	.131	23.511	....
	4	.234	.087	1.00	....
	5	.257	.102	1.678	....
	6	.306	.219	23.619	....
	7	.342	.208	19.108	....
Feuchy	1	.329	.183	6.948	....
	2	.254	.086	.78	....
	3	.316	.092	1.124	....
	4	.165	.103	.55	....
	5	.317	.285	27.373	....
	6	.403	.189	7.627	....
Coupelle-Vielle	1	.232	.10	4.968	....
Boiry-Notre-Dame	1	.306	.092	.715	....
	2	.275	.092	.756	....
	3	.292	.088	.745	....
	4	.268	.088	.817	....
	5	.242	.093	1.069	....
	6	.277	.081	1.377	....
	7	.185	.043	.258	....
	8	.276	.098	.50	....
	9	.281	.077	.76	....
	10	.30	.086	.753	....
	11	.321	.185	18.21	....

Chemical composition of the soils of France—Continued.

PAS-DE-CALAIS—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Boiry-Notre-Dame	12	0.297	0.073	0.64	...
	13	.28	.082	.372	...
	14	.251	.078	.616	...
Givenchy-en-Gohelle	1	.315	.136	1.224	...
	2	.366	.132	1.283	...
	3	.386	.155	3.864	...
	4	.282	.127	.88	...
	5	.367	.124	5.42	...
	6	.436	.178	5.891	...
Penin	1	.306	.119	.769	...
	2	.261	.149	9.243	...
	3	.333	.149	3.681	...
	4	.203	.202	63.776	...
	5	.267	.139	1.119	...
	6	.331	.14	2.472	...
Baralle	1	.245	.093	2.246	...
	2	.224	.102	1.763	...
	3	.262	.272	14.719	...
	4	.289	.133	.741	...
	5	.269	.249	9.838	...
	6	.331	.164	3.219	...
Rebergues	1	.35	.206	14.421	...
	2	.647	.126	1.495	...
	3	.27	.222	47.525	...
	4	.32	.373	11.439	...
	5	.384	.164	81.513	...
	6	.189	.312	17.655	...
Agny	1	.39	.682	19.799	...
	2	.251	.163	2.265	...
	3	.236	.135	2.095	...
	4	.38	.192	4.135	...
	5	.298	.246	5.20	...
	6	.30	.258	11.348	...
Auchy-l-Hesdin	1	.221	.202	1.268	...
	2	.176	.239	47.327	...
	3	.208	.21	7.066	...
	4	.239	.125	4.61	...
Herbelles	1	.244	.097	.708	...
	2	.27	.114	.273	...
	3	.238	.093	.765	...
	4	.241	.201	43.37	...
	5	.206	.095	.586	...
	6	.336	.155	7.123	...
Beussent	1	.411	.187	16.211	...
	2	.241	.134	51.008	...
	3	.293	.084	2.564	...
	4	.369	.135	3.493	...
	5	.273	.096	.716	...
	6	.224	.116	5.975	...
Divion	1	.224	.084	.978	...
	2	.237	.124	3.626	...
	3	.167	.046	.434	...
	4	.257	.116	4.754	...
	5	.19	.096	.869	...
	6	.239	.176	2.583	...
Aix-en-Issart	1	.328	.091	.331	...
	2	.323	.142	.888	...
	3	.292	.116	.316	...
	4	.152	.307	36.02	...
	5	.259	.09	1.004	...
	6	.247	.167	6.025	...
Hermies	1	.40	.269	6.881	...
	2	.341	.167	6.882	...
	3	.327	.159	2.329	...
	4	.27	.17	4.729	...
	5	.289	.124	.561	...
	6	.269	.138	1.413	...
Cherisy	1	.202	.121	1.026	...
	2	.228	.34	23.132	...
	3	.336	.133	.924	...
	4	.322	.20	.975	...
	5	.259	.174	3.929	...
	6	.173	.162	.839	...
Guarbecque	1	.296	.10	1.245	...
	2	.337	.097	1.114	...
	3	.294	.13	2.24	...
	4	.302	.128	1.312	...
	5	.219	.065	.788	...
	6	.308	.106	2.146	...

Chemical composition of the soils of France—Continued.

PAS-DE-CALAIS—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Izel-les-Hameau	1	0.202	0.107	0.646	....
	2	.219	.225	38.899	....
	3	.279	.121	1.975	....
	4	.26	.087	.618	....
	5	.209	.091	.808	....
	6	.303	.12	2.784	....
	7	.277	.111	1.671	....
Camiers	1	.125	.179	48.777	....
	2	.119	.07	2.05	....
	3	.329	.379	9.588	....
	4	.213	.089	1.746	....
	5	.181	.163	41.025	....
	6	.235	.144	68.206	....
	7	.156	.119	6.145	....
	8	.207	.089	.277	....
Le Transloy	1	.242	.081	.914	....
	2	.279	.122	.52	....
	3	.217	.093	.426	....
	4	.219	.118	.537	....
	5	.254	.132	1.247	....
	6	.296	.121	.769	....
Blendecques	1	.26	.075	.877	....
	3	.186	.08	.175	....
	5	.133	.089	.289	....
	7	.205	.101	2.063	....
	9	.22	.203	11.44	....
	11	.192	.167	13.74	....
Fleurbaix	1	.321	.09	.997	....
	2	.34	.083	.94	....
	3	.372	.113	.739	....
	4	.358	.105	2.086	....
Bernieulles	1	.277	.083	.322	....
	2	.275	.079	5.241	....
	3	.239	.091	.854	....
	4	.221	.081	2.599	....
	5	.214	.089	1.053	....
	6	.339	.077	4.612	....
Duisans	1	.235	.111	1.348	....
	2	.361	.198	2.94	....
	3	.298	.089	.834	....
	4	.326	.12	.528	....
	5	.281	.158	1.989	....
	6	.209	.221	48.356	....
	7	.292	.126	5.413	....
Bucquoy (Essart)	1	.233	.08	6.333	....
	2	.275	.136	1.469	....
	3	.268	.146	.606	....
	4	.272	.135	.546	....
	5	.27	.133	.528	....
Louez	3	.291	.213	4.702	....
Ablainzevelle	5	.245	.172	.575	....
	6	.287	.132	.661	....
Frevent	8	.265	.088	1.069	....
Les Attaques	10	.226	.148	13.177	....
Ablainzevelle	11	.236	.096	.527	....
Oisy-le-Verger	13	.337	.094	1.367	....
Lumbres	14	.292	.108	2.378	....
	15	.212	.157	5.747	....
Lagnicourt	16	.343	.119	1.328	....
Bethune	17	.303	.144	1.59	....
Bapaume	19	.283	.105	.625	....
Campagne-les-Hesdin	21	.222	.103	.985	....
Fouquieres	23	.231	.072	5.201	....
Bapaume	25	.223	.122	.775	....
Oignies	26	.206	.063	.586	....
Auchy-lez-La-Bassee	28	.238	.133	2.201	....
Oignies	1	.18	.053	.455	....
Ecoust-Saint-Mein	1	.258	.182	2.172	....
	2	.284	.124	.827	....
	3	.256	.128	.586	....
Béthune	1	.209	.09	1.379	....
	2	.224	.092	1.031	....

Chemical composition of the soils of France—Continued.

BOUCHES-DU-RHONE.[a]

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
La Crau	1	0.241	0.099	0.35	0.482
	2	.221	.088	.708	.382
	3	.204	.088	1.64	.498
	4	.177	.103	.464	.616
	5	.416	.128	1.588	.56
	6	.339	.091	.384	.37
	7	.491	.053	.972	.612
	8	.341	.197	12.00	.854
Limon de Durance		.26	.102	23.75	.833
		.252	.108	20.905	.989
		.353	.109	23.12	1.15
		.312	.104	20.777	.94
Limon du Rhone		.396	.118	23.05	.358
Sables du Rhone	1	.213	.112	.666	31.50
	2	.20	.101	.53	32.40
	3	.082	.094	.32	16.83
	4	.07	.078	.56	18.30
	5	.062	.069	.52	19.30
	6	.094	.104	.587	19.80
	7	.091	.094	.586	20.20
	8	.062	.069	.421	24.50
	9	.093	.078	.629	22.50
	10	.059	.101	.48	23.60
	11	.06	.077	.547	21.41
	12	.06	.093	.53	27.65
	13	.111	.135	.404	18.40
	14	.085	.15	.157	34.45
	15	.065	.129	.437	22.10
	16	.076	.124	.53	22.15
	17	.111	.15	.52	21.45
	18	.163	.148	.648	22.10
	19	.066	.078	.530	17.30
	20	.073	.096	.578	17.56
	21	.399	.13	1.657	30.30
	22	.198	.14	.684	24.40
	23	.129	.122	.731	19.00
	24	.21	.138	.462	21.70
	25	.078	.106	.547	20.40
	26	.085	.13	.478	18.76
	27	.085	.126	.58	22.28
	28	.074	.111	.534	20.00
	29	.316	.165	.892	25.25
	30	.181	.128	.606	20.30
	31	.153	.134	.597	20.25
	32	.222	.18	.714	22.44
	33	.236	.137	.86	26.40
	34	.075	.076	.612	18.24
La Camargue	1	.224	.159	1.136	31.87
	2	.212	.16	.944	33.59
	3	.419	.169	1.048	32.60
	4	.76	.155	1.387	34.50
	5	.545	.145	1.106	33.87
	6	.29	.145	1.162	33.97
	7	.418	.153	1.228	31.85
	8	.224	.139	1.518	32.40
	9	.183	.14	.875	24.20
	10	.217	.16	.94	25.21
	11	.249	.147	1.080	32.75
	12	.298	.15	1.039	32.22
	13	.412	.133	1.51	35.85
	14	.308	.14	1.107	29.80
	15	.268	.145	1.104	33.75
	16	.255	.14		32.50
	17	.21	.125	1.201	31.92
	18	.278	.135	1.065	32.14
	19	.429	.16	1.013	30.95
	20	.152	.153	.992	25.60
	21	.374	.099	1.046	34.86
	22	.472	.108	1.096	32.90
	23	.547	.125	.974	38.62
	24	.437	.143	1.104	33.70
	25	.49	.138	1.042	34.70
	26	.525	.144	1.065	36.40

[a] Gastine. Ann. Sci., Agron., 1898, 155, 240. Bull. Min. Agr., France, 1897, pp. 614–655.

Chemical composition of the soils of France—Continued.

MARNE.[a]

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Verzy: Verzenay	1	0.171	0.205	14.50	0.007
	2	.186	.134	19.00	.036
	3	.237	.215	17.50	.011
	4	.115	.169	14.10	.009
	5	.186	.122	10.15	.126
Verzy	1	.205	.18	8.20	.003
	2	.136	.186	18.30	.007
	3	.19	.216	10.20	.043
	4	.169	.133	8.00	.034
	5	.135	.095	1.74	.091
Villers-Marmery	1	.241	.186	9.30	.092
	2	.219	.17	12.50	.101
	3	.278	.195	14.00	.106
	4	.252	.142	2.30	.086
	5	.258	.242	25.20	.139
	6	.18	.264	26.80	.097
	7	.168	.200	19.60	.048
Ville-en-Tardenois: Pargny	1	.186	.153	32.10	.164
	2	.168	.123	27.80	.137
	3	.246	.111	14.50	.288
	4	....	.058	36.00	....
	5	.23	.089	16.50	.205
	6	.144	.061	4.00	.108
Villedomange	1	.263	.165	9.30	.262
	2	.281	.13	13.30	.249
Courmas	1	.534	.094	30.50	.146
	2	.622	.08	22.50	1.124
Bouzy	1	.139	.161	11.35	.295
	2	.257	.14	8.85	.016

CHARANTE-INFERIEURE.[b]

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
Perigny	....	0.434	0.089	....	....
	....	.482	.142	....	....
Chevillon	....	.778	.146	....	....
	....	.379	.124	....	....
	....	.742	.147	....	....

LOIRE-INFERIEURE.[c]

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
Nozay	1	0.07	0.08	0.07	0.07
	2	.05	.04	.05	.10
	3	.04	.04	.05	.04
	4	.10	.05	.13	.20
	5	.02	.07	.02	.02
	6	.05	.06	.09	.05
	7	.07	.03	.02	.08
	8	.13	.16	.09	.17
	9	.02	.17	.04	.02
	10	.07	.02	.09	.11
	11	.03	.09	.03	.05
	12	.11	.07	.11	.12
	13	.03	.05	.03	.03
	14	.05	.05	.03	.03
	15	.06	.15	.07	.03
	16	.10	.14	.12	.08
	17	.08	.12	.09	.14
	18	.08	.13	.07	.10
	19	.09	.15	.10	.16
	20	.12	.14	.12	.26
	21	.04	.08	.04	.04
	22	.11	.14	.09	.16
	23	.05	.10	.11	.06
	24	.04	.13	.11	.06
	25	.05	.13	.08	.06
	26	.06	.15	.04	.06
	27	.04	.11	.05	.01
	28	.11	.12	.07	.06
	29	.11	.13	.04	.09

[a] Muntz. Bull. Min. Agr., France, 1893, 170–210.
[b] Verneuil. Prog. Agr. Viticole, 21, 491 (1894).
[c] Bourgeois. Rapports, 1891.

Chemical composition of the soils of France—Continued.

LOIRE-INFERIEURE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Nozay	30	0.06	0.09	0.06	0.05
	31	.04	.05	.04	.02
	32	.07	.08	.06	.05
	33	.06	.08	.09	.06
	34	.13	.11	.13	.05
	35	.08	.01	.07	.02
	36	.07	.03	.02	.01
	37	.05	.03	.02	.01
	38	.03	.04	.04	.03
	39	.05	.04	.06	.08
	40	.06	.10	.17	.11
	41	.04	.03	.05	.05
	42	.06	.03	.05	.06
	43	.04	.08	.03	.02
	44	.07	.05	.11	.04
	45	.05	.05	.07	.05
	46	.10	.06	.07	.06
	47	.18	.07	.04	.03
	48	.09	.13	.08	.08
	49	.06	.12	.05	.05
	50	.13	.14	.08	.04
	51	.12	.12	.11	.10
	52	.10	.13	.11	.06
	53	.11	.10	.13	.05
	54	.15	.11	.12	.07
	55	.13	.10	.11	.05
	56	.11	.11	.11	.13
	57	.09	.09	.11	.06
	58	.12	.09	.07	.08
	59	.09	.10	.10	.09
	60	.11	.10	.10	.10
	61	.16	.13	.18	.07
	62	.09	.10	.10	.11
	63	.10	.12	.15	.14
	64	.09	.11	.08	.10
	65	.09	.05	.11	.23
	66	.03	.04	.04	.19
	67	.03	.05	.06	.21
	68	.04	.05	.06	.19
	69	.08	.11	.12	.39
	70	.13	.11	.15	.43
	71	.08	.08	.09	.25
	72	.07	.07	.06	.19
	73	.08	.06	.14	.25
	74	.14	.06	.07	.19
	75	.07	.06	.07	.15
	76	.09	.03	.11	.07
	77	.03	.02	.04	.04
	78	.05	.02	.06	.07
	79	.02	.02	.04	.04
	80	.04	.01	.05	.08
	81	.02	.01	.02	.05
	82	.06	.01	.06	.09
	83	.09	.05	.07	.05
	84	.03	.02	.03	.02
	85	.07	.08	.12	.04
	86	.11	.10	.13	.07
	87	.09	.06	.09	.04
	88	.12	.10	.15	.10
	89	.05	.05	.08	.04
	90	.05	.07	.08	.08
	91	.07	.02	.04	.05
	92	.04	.03	.04	.01
	93	.09	.08	.14	.11
	94	.06	.05	.08	.16
	95	.09	.05	.10	.05
	96	.13	.06	.14	.08
	97	.12	.08	.19	.11
	98	.11	Traces.	.02	.05
	99	.10	.05	.14	.07
	100	.14	.08	.09	.08
	101	.13	.06	.19	.10
	102	.12	.02	.14	.10
	103	.15	.08	.22	.16
	104	.12	.05	.19	.12
	105	.08	.09	.20	.14
	106	.06	.09	.10	.05

Chemical composition of the soils of France—Continued.

LOIRE-INFERIEURE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Nozay	107	0.19	0.10	0.15	0.12
	108	.07	.07	.11	.06
	109	.08	.11	.15	.10
	110	.13	.12	.16	.18
	111	.09	.12	.13	.12
	112	.04	.12	.31	.02
	113	.08	.10	.24	.07
	114	.09	.11	.15	.10
	115	.08	.09	.20	.11
	116	.10	.11	.20	.10
	117	.13	.13	.17	.12
	118	.06	.07	.19	.12
	119	.10	.13	.10	.12
	120	.15	.14	.14	.23
	121	.07	.09	.08	.04
	122	.03	.04	.04	.06
	123	.08	.12	.31	.11
	124	.05	.11	.23	.06
	125	.05	.15	.23	.08
	126	.07	.12	.13	.08
	127	.11	.10	.13	.15
	128	.12	.10	.10	.13
	129	.13	.14	.09	.08
	130	.08	.06	.13	.05
	131	.10	.14	.09	.06
	132	.20	.07	.15	.22
	133	.13	.05	.09	.12
	134	.06	.04	.05	.05
	135	.08	.07	.15	.06
	136	.06	.07	.07	.04
	137	.07	.08	.12	.07
	138	.09	.07	.12	.08
	139	.03	.03	.05	.02
	140	.02	.03	.04	.02
	141	.14	.09	.32	.12
	142	.07	.07	.09	.06
	143	.07	.11	.11	.06
	144	.05	.18	.62	.13
	145	.06	.09	.15	.06
	146	.09	.04	.05	.05
	147	.12	.08	.18	.07
	148	.09	.04	.10	.21
	149	.08	.08	.13	.21
	150	.10	.04	.11	.13
	151	.10	.07	.09	.14
	152	.10	.07	.09	.11
	153	.08	.06	.06	.16
	154	.13	.03	.10	.16
	155	.10	.07	.18	.26
	156	.11	.05	.12	.15
	157	.06	.02	.04	.07
	158	.07	.05	.05	.10
	159	.07	.03	.08	.06
	160	.03	.02	.06	.07
	161	.12	.05	.08	.14
	162	.07	09	.05	.09
	163	.09	05	.05	.11
	164	.06	.02	.06	.05
	165	.08	.03	.08	.31
	166	.13	.04	.09	.28
	167	.04	.03	.05	.06
	168	.05	.07	.08	.07
	169	.04	.04	.08	.04
	170	.21	.06	.14	.37
	171	.10	.07	.11	.20
	172	.13	09	.20	.33
St. Viand: Plessis-Grimaud (appx. 250 hectares)	1	.07	.03	.16	.13
	2	.21	.04	.17	.15
	3	.17	.04	.29	.27
	4	.14	.04	.26	.16
	5	.12	.06	.16	.12
	6	.23	.08	.13	.21
	7	.21	.06	.10	.26
	8	.09	.06	.15	.06
	9	.17	.04	.16	.19
	10	.20	.09	.13	.14
	11	.24	.03	.35	.60

Chemical composition of the soils of France—Continued.

LOIRE-INFERIEURE—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
St. Viand: Plessis-Grimand (appx. 250 hectares)	12	0.12	0.06	0.32	0.23
	13	.14	.06	.18	.12
	14	.22	.08	.18	.31
	15	.19	.07	.12	.30
	16	.16	.07	.16	.24
	17	.21	.06	.18	.56
	18	.17	.05	.47	.37
	19	.10	.09	.16	.44
	20	.14	.05	.30	.23
	21	.14	.04	.24	.20
	22	.15	.06	.08	.14
	23	.21	.05	.30	.17
	24	.15	.06	.15	.31
	25	.10	.05	.18	.24
	26	.16	.06	.27	.33
	27	.12	.04	.14	.18
	28	.18	.06	.11	.26
	29	.15	.08	.22	.15
	30	.10	.07	.39	.23
	31	.17	.08	.18	.25
	32	.15	.09	.33	.34
	33	.12	.04	.12	.38
	34	.11	.06	.12	.40
	35	.20	.06	.10	.12
	36	.09	.04	.07	.03
	37	.10	.10	.06	.04
	38	.18	.06	.08	.07
	39	.20	.06	.20	.09
	40	.18	.08	.12	.51
	41	.12	.04	.11	.12
	42	.15	.07	.21	.76
	43	.10	.06	.15	.54
	44	.11	.05	.12	.45
	45	.15	.06	.27	.39
	46	.20	.06	.12	.20
	47	.14	.08	.22	.17
	48	.12	.04	.06	.27
	49	.25	.08	.09	.20
	50	.12	.04	.05	.04
	51	.18	.07	.21	.36
	52	.20	.08	.10	.25
	53	.22	.06	.16	.34
	54	.12	.07	.09	.21
	55	.20	.06	.10	.12
	56	.22	.09	.18	.37
	57	.25	.06	.15	.31
	58	.25	.03	.17	.51
	59	.24	.07	.12	.11
	60	.22	.05	.09	.05
	61	.23	.07	.07	.09
	62	.21	.05	.09	.20
	63	.22	.07	.27	.10
	64	.15	.06	.10	.12
	65	.12	.05	.20	.15
	66	.13	.06	.19	.17
	67	.10	.04	.47	.13
	68	.14	.05	.13	.10
	69	.18	.06	.11	.09
	70	.17	.05	.38	.53
	71	.51	.04	.17	.12
	72	.16	.04	.18	.10
	73	.15	.04	.16	.09

L'HERAULT.[a]

Capestang: Alluvions de Capestang	1	0.131	0.095	15.164	....
	2	.114	.087	8.512	....
Murveil: Alluvions de l'orb	3	.117	.132	2.918	....
Thegan	4	.158	.107	3.87	....
Lignan	5	.10	.07	.006	....
Sauvian	6	.172	.09	.437	....
Lignan	7	.149	.138	3.466	....

[a] Lagatu and Semichon. Matériaux pour une Ėtude des Terres de Département de l'Hérault, 1893; Prog. Agr. et. Vitu. 19, 105, 162, 179, 233, 276, 447, 489 (1893).

Chemical composition of the soils of France—Continued.

L'HERAULT—Continued.

Description and locality	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Beziers	8	0.139	0.146	5.60	
	9	.131	.179	3.816	
Villeneuve	10	.175	.134	2.635	
	11	.182	.15	4.584	
Lieuran: Alluvions de Libron		.134	.101	6.889	
Beziers		.109	.071	1.38	
Servian: Alluvions de la Tongue		.15	.137	6.368	
		.171	.108	8.288	
		.171	.154	6.944	
Saint-Thibery: Alluvions de l'Herault		.164	.155	7.224	
Bessan		.195	.14	7.28	
		.168	.20	7.112	
Agde		.174	.167	8.344	
		.20	.133	8.848	
Agde: Sables des dunes		.047	.088	11.088	
Lieuran: Diluvium de l'Epinouse		.167	.04	1.686	
Servian		.143	.042	.003	
Saint-Thibery		.192	.055	.431	
		.076	.06	.781	
		.147	.056	.896	
Beziers		.135	.047	.706	
Servian: Depots fluvio-volcanique		.122	.26	3.147	
Agde: Terrain pliocene		.258	.114	1.419	
		.121	.082	17.64	
Servian		.164	.081	3.214	
Autignec: Terrain miocène		.102	.15	12.712	
Murveil		.127	.095	6.72	
Pomerols		.20	.119	10.92	
Murveil		.103	.121	15.904	
Beziers		.044	.052	15.848	
Maureilham		.098	.157	15.344	
Capestang		.134	.162	11.76	
Pinet		.188	.054	17.304	
Beziers		.105	.177	24.136	
		.266	.136	28.836	
Pinet		.212	.038	30.408	
Beziers		.131	.092	14.84	
		.236	.139	23.016	

DORDOGNE.[a]

Terrains granitiques		0.255	0.034	0.012	
		.244	.0492	.0556	
		.235	.046	.0491	
				$CaCO_3$	
Terrains cretaces		.08	.0796	16.00	
		.069	.095	64.00	
Sables du Perigord		.0812	.0256	Traces.	
Saint-Nexans		.1445	.0256	Traces.	
Lunas: Bouvees Argilo-siliceuses		.059	.023		
Bouvees silico argileuses				$CaCO_3$	
Leves		.209	.069	22.40	
Saint-Alveres		.075	.079	16.00	
Laudais: Terrains tertiaires		.097	.02	.119	
		.195	.051	2.77	
		.258	.056	2.24	
		.319	.059	1.39	
Terrains quaternaires		.15	.0703	.2225	0.125
		.189	.0615	.184	

MEURTHE-ET-MOSELLE.[b]

Cirey: Grès Bigarres		0.1717	0.0523	0.0364	0.075
Bertrichamp: Gres Bigarres		.0901	.0212	.028	.10
Marnes		.1819	.0559	.0532	.05
Argile		.1972	.0634	.1512	.08

[a] Ann. Inst. Nat. Agron., France, 14, 61 (1891–92).
[b] Bull. Sta. de la Loire-Inférieure, 1903–4.

Chemical composition of the soils of France—Continued.

HAUTE-PYRENEES.[a]

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime ($CaCO_3$).	Magnesia (MgO).
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Vallée de Luz	....	0.455	0.123	0.0107	....
Prairie irrigeree	....	.098	.202	.0171	....
Prairie tourbeuse	....	.097	.394	.082	....
Prairie seche	....	.287	.128	.0137	....

EURE-ET-LOIRE.

	1	0.096	0.069	0.84	0.148
	2	.081	.039	.39	.10
	3	.096	.051	.49	.092
	4	.105	.045	.91	.096
	5	.084	.056	1.09	.079
	6	.086	.036	.84	.086
	7	.076	.034	.53	.073
	8	.098	.061	.60	.084
	9	.072	.060	.47	.075
	10	.079	.047	.42	.078
	11	.086	.051	.58	.086

ÉPERNAY.[b]

Aoise: Mesnil-sur-Oger	1	0.178	0.186	28.95	0.025
	2	.169	.157	41.65	.093

[a] Faure. Ann. Inst. Nat. Agron. 13, 117 (1888–91).
[b] Station Agrm. de Chartres, Rapports, 1891–1892.

Chemical composition of the soils of Germany.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5)	Lime (CaO).	Magnesia (MgO).
HESSE.[a]		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Bundsandstein	....	0.25	0.17	0.35	0.31
		.32	.13	.39	.38
		.31	.12	.37	.30
Basalt	....	.11	.15	.89	1.16
Graudwacke	....	.23	.18	.30	1.15
Muschelkalk	....	.14	.09	.52	1.75
"Taunusgesteine"	243	.15	.07	.10	.06
Devonien	411	.21	.02	.13	.08
"Rotliegendes"	67	.57	.12	3.16	1.13
Tertiary	6	.37	.10	14.97	1.76
	15	.37	.11	12.41	1.42
	1	.45	.05	20.20	.83
	5	.29	....	28.80	2.16
	3	.31	.12	5.55	.78
	19	.31	.12	13.60	.78
Diluvium	25	.38	.06	.38	.06
	58	....	.06	3.24	.08
	7	.19	.09	15.95	1.50
	8	.26	.26	6.85	1.05
	16	.22	.15	6.46	.45
	16	.11	.25	17.68	2.07
Alluvium	10	.35	....	2.12	.63
	21	.23	.14	3.41	.42
	20	.29	.25	4.73	.83
	12	.21	....	9.00	.37
PRUSSIA.[b]					
Köslin:[c]					
Koppenow	....	.094	.0709	.109	....
Zdrewen	....	.133	.0853	.2505	....
Dubberzin	....	.0936	.0603	.2243	....

[a] Habernoll, Mitt. Landw. Inst. könig. Univ. Breslau, 2, 147 (1899). Haselhoff, Fühlings landw. Ztg., 55–73 (1906).
[b] Baessler, Ber. Thāt. Agrik.-Chem. Vers. Samenc, Köslin, 1898, 1900.
[c] The potash analyses were made with 10 per cent hydrochloric acid. The phosphoric acid and lime results are based upon complete analyses.

Chemical composition of the soils of Germany—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
PRUSSIA—continued.					
Köslin—Continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Grosz-Silber	...	0.0572	0.0653	0.1991	...
		.0577	.0488	.1336	...
Reinwasser	...	.0541	.0841	.1292	...
Kl.-Spiegel	...	.069	.118	.05	...
		.076	.075	.067	...
Garden	...	.068	.037	.134	...
Menhans	...	.06	.044	.109	...
Helenenau	...	.065	.065	.095	...
Gr.-Raddow	...	.044	.06	.082	...
Landechow	...	.083	.089	.156	...
Schinz	...	.038	.053	.035	...
Breitenberg	...	.058	.099	.185	...
Schmolsin	...	.03	.079	.072	...
Gr.-Mellen	...	.026	.092	.048	...
Knick	...	.03	.072	.15	...
WEST PRUSSIA.[a]					
Kainozoic	...	.081	.105	.182	0.422
		.065	.096	.147	.199
		.068	.094	.153	.175
		.052	.094	.14	.154
		.049	.098	.14	.137
		.027	.09	.233	.163
		.039	.053	.171	.059
		.078	.133	.783	.261
		.037	.069	.087	.044
		.078	.106	.898	.333
		.061	.065	.70	.103
		.061	.042	.847	.43
		.092	.054	.20	.028
Mesozoic	...	.039	.018	.683	.042
		066	.053	.343	.103
		.103	.03	2.507	.533
		.113	.025	22.067	.113
		.031	.06	3.24	.202
		.039	.021	.183	.144
		.056	.045	.347	.084
		.039	.047	.127	.096
		.05	.083	.027	.017
		.077	.115	.28	.065
		.047	.169	.386	.048
Paleozoic	...	.135	.058	4.403	.216
		.144	.171	2.60	.37
		.026	.034	.087	.019
		.188	.235	.297	.659
		.123	.192	1.63	.144
		.04	.028	Trace.	.019
		.129	.092	.293	.072
Eruptive rocks	...	.179	.041	.753	.176
		.212	.219	1.849	.574
WEST PRUSSIA.[b]					
Humus soils	3	.14	.22	1.03	...
	8	.34	.44	2.85	...
	13	.10	.13	1.40	...
	21	.05	.29	2.37	...
Heavy soils	5	.15	.35	1.91	...
	7	.48	.13	.88	...
	9	.21	.32	.77	...
	11	.17	.11	.19	...
	17	.30	.09	.86	...
	20	.17	.12	.84	...
	22	.75	.13	1.77	...
	23	.23	.11	.41	...
	27	.58	.13	.67	...
	28	.25	.10	.31	...
	29	.18	.09	.44	...
Medium soils	1	.17	.09	.38	...
	2	.11	.08	.19	...
	12	.13	.05	.40	...
	14	.17	.08	.35	...
	18	.16	.12	.27	...
	24	.16	.09	.17	...
	25	.09	.09	.16	...
	26	.19	.16	6.40	...

[a] Wohltmann, Das Nahrestoff-Kapital west-deutscher Böden, Bonn, 1901. Analyses with cold hydrochloric acid.

[b] Schmoeger Landw. Jahrb., vol. 34, p. 160 (1905). Blanck, Landw. Vers.-Sta., 60, 405 (1904). The first 2 soils were treated with hot concentrated hydrochloric acid. The following 5 soils were treated with double strength hydrochloric acid, and for the last 2 soils complete analyses are given.

Chemical composition of the soils of Germany—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
WEST PRUSSIA—continued.		*Per cent.*	*Per cent*	*Per cent.*	*Per cent.*
Light soils	4	0.21	0.10	0.18	....
	6	.11	.23	.43	....
	10	.04	.19	.11	....
	15	.07	.08	.13	....
	16	.07	.09	.18	....
	19	.07	.09	.26	....
	30	.08	.10	.17	....
Westphalia[a] Lünten Dörmern	1	.047	.016	.076	....
	9	.063	.036	.128	....
	20	.265	.028	.077	....
	26	.066	.02	.40	....
	4	.049	.022	.157	....
	3	.419	.061	.571	....
	2	.074	.016	.157	....
	18	.024	.016	.225	....
	11	.148	.023	.152	....
	5	.304	.015	.081	....
	13	.129	.019	.251	....
	22	.031	.019	.178	....
	24	.025	.026	.192	....
	25	.03	.011	.103	....
	26	.066	.029	.40	....
	7	.149	.04	.027	....
	8	.05	.012	.017	....
	5	.304	.015	.081	....
	16	.256	.01	.025	....
Wettringen, Bilk, and Haddrup:					
I (a)	0	.029	.03	.097	0.063
	3	.033	.018	.192	.045
	5	.051	.003	.133	Trace.
	8	.019	.011	.007	Trace.
	9	.04	.01	.007	Trace.
	15	.019	Trace.	.079	.048
I.	0	.092	.02	.036	.032
	1	.063	.009	.30	.032
	4	.04	.021	.01	.029
	9	.024	.021	.029	.031
	11	.009	.003	.05	.036
	14	....	....	....	....
	16	.014	.092	.125	Trace.
	19	.033	.029	.148	.043
	31	.06	.038	.255	.034
II.	1	.019	Trace.	.075	.039
	2	.01	.070	.126	.071
	5	.033	.022	.097	.016
	6	.032	.01	.203	.00
	12	.069	.00	.00	.00
	16	.023	.016	.056	.00
	19	....	....	....	....
	21	.023	.016	.089	.00
	22	....	....	....	....
	23	....	....	....	....
	24	....	....	....	....
	25	.051	Trace.	.032	.01
III.	1	.049	.014	.143	.003
	2	.025	.008	.00	.018
	5	.057	Trace.	.072	.035
	10	.04	.005	Trace.	.033
	11	....	....	....	....
	13	.018	.006	.18	Trace.
IV.	1	.019	.00	.01	.00
	5	.024	.014	.003	.024
	10	.05	.007	.138	.004
V.	1	.013	.006	.176	.025
	3	.014	.017	.182	.014
	5	.066	.066	.058	.20
	8	.014	.00	.129	.031
	9	....	....	....	....
VI.	1	.028	.03	.014	.008
	2	.024	.018	.028	.014
	4	....	....	....	....
	5	....	....	....	....
	6	.016	.023	.286	.083

[a] Haselhoff and Breme. Die Haideböden. Westfalens, 1899 to 1903.

Chemical composition of the soils of Germany—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
WEST PRUSSIA—continued.					
Wettringen, Bilk, and Haddrup—Cont'd.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent*
VII	2	0.016	0.015	0.021	0.021
	7	.019	.015	.261	.003
	8	....	....	....	....
	16	.003	.012	.025	.007
	22	.027	.014	.05	Trace.
	23	....	....	....	....
VIII	1	.022	.11	.05	Trace.
	5	....	....	....	....
	8	.014	.056	.075	.023
	12	.038	.031	.072	.028
	13	....	....	....	....
	16	.027	.007	.01	.016
	20	.028	.018	.063	.002
IX	2	.091	.066	.063	.102
	3	....	....	....	....
	12	.05	.026	.043	.099
	14	.023	.00	.041	.081
	20	.029	.00	.051	.092
	21	.032	.00	.075	.037
	24	....	....	....	....
	28	.036	.028	.083	.018
	32	.049	.013	.065	.017
X	3	....	....	....	....
	4	.027	.016	Trace.	.031
	9	.061	.014	Trace.	.014
	13	.044	.023	.155	.004
	16	.053	.013	.075	Trace.
Handorf and Telgte	3	.008	.071	.112	.018
	6	.075	.012	.023	.008
	1	.057	.019	.077	.022
	2	.088	.032	.135	.017
	3	.026	.025	.119	.005
	5	.012	.038	.00	.008
	10	.106	.028	.114	.032
	15	.127	.051	.046	.129
	20	.114	.053	.165	.131
	1	.103	.041	.023	.17
	8	.037	.043	.112	.123
	10	.05	.032	.096	.037
	18	.068	.097	.092	.08
	20	.025	.16	.16	.14
St. Mauritz, Gelmer, and Gimbte	3	.023	.039	.365	.062
	4	.129	.027	.178	....
	5	.071	.028	.042	Trace.
	7	.01	.039	.543	.045
	8	.201	.028	.337	.094
	9	.086	.036	.117	.00
	12	.157	.058	.154	.02
	3	.023	.039	.365	.062
	4	.129	.027	.178	....
	8	.201	.028	.337	.094
	12	.053	.024	.348	.00
	15	.093	.04	.138	.01
Wiedenbrück	....	.054	.021	.12	.113
		.083	.053	.348	.053
		.083	.062	.288	.079
		.073	.07	.961	.278
		.06	.032	.108	.049
		.073	.006	.075	.021
		.115	.024	.14	.054
		.045	.011	.063	.023
		.009	.022	.048	.017
		.148	.011	.418	.082
		.023	.078	.183	.076
		.146	.10	.105	.081
		.048	.027	.194	.045
		.006	.009	.052	.01
		.022	.059	.088	.031
		.004	.016	.073	.027
		.004	.023	.116	.032
		.014	.032	.174	.191
		.025	.037	.091	.028
		.006	.031	.079	.02
		.051	.066	.205	.013
		.021	.034	.113	.014

Chemical composition of the soils of Germany—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
WEST PRUSSIA—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Weidenbrück		0.017	0.029	0.08	0.015
		.02	.029	.04	.03
		.101	.03	.165	.012
		.092	.013	.03	.009
		.018	.018	.21	.026
		.040	.029	.04	.026
		.064	.014	.061	.011
		.043	.027	.12	.01
		.017	.085	.048	.015
		.088	.024	.093	.054
		.157	.015	.078	.032
		.07	.034	.085	.016
		.021	.03	.012	.015
		.039	.014	.028	.011
		.014	.064	.038	.009
		.042	.009	.063	.022
		.123	.014	.08	.035
		.019	.016	.14	.02
		.033	.032	.23	.002
		.061	.022	.51	.058
		.041	.015	.035	.003
		.076	.006	.048	.006
		.085	.01	.028	...
		.04	.011	.023	...
		.024	.021	.073	.035
		.033	.041	.09	.038
		.052	.038	.07	.042
		.042	.023	.10	.027
		.056	.026	.178	.034
		.029	.008	.035	.016
		.058	.019	.08	.016
		.025	.022	.023	.013
		.051	.021	.04	.008
		.035	.009	.02	...
		.06	.032	.025	.022
		.016	.035	.15	.02
		.013	.029	.143	.021
		.099	.013	.043	.014
		.032	.018	.055	.011
		.047	.035	.043	Trace.
		.053	.019	.045	Trace.
		.062	.029	.04	.014
		.051	.003	.045	.009
		.126	.032	.035	.001
		.165	.012	.038	.005
		.041	.013	.062	.023
		.031	.009	.074	.009
		.015	.027	.123	.007
		.03	.066	.055	.005
		.063	Trace.	.012	Trace.
		.042	.005	.023	Trace.
		.036	.006	.09	.007
		.034	.011	.11	Trace.
		.048	Trace.	.038	Trace.
		.008	.021	.12	Trace.
		.079	.006	.005	Trace.
		.091	.021	.013	.007
		.065	.008	.01	Trace.
Arendsee [a]		.055	.048	.343	.041
Wessing [a]		.116	.158	.317	.132
Harpe [a]		.074	.072	.912	.048
Schurigshoff [a]		.094	.05	.285	.074
Schwemsal [a]		.191	.093	.563	.342
Lauchstadt [a]		.446	.084	.984	.52
Vitzenburg [a]		.339	.148	5.75	1.666
Wessnig [a]		.167	.08	.503	.338
		.510	.814	4.019	1.257
		.277	.158	.81	.836
EAST PRUSSIA					
		.3336	.1180	1.059	.2026
		.3486	.1113	1.093	.1529
		.68	.09	.41	1.16
		.81	.18	.48	1.87
		.14	.13	.50	1.17
		.15	.11	.38	.79
		.34	.11	1.08	.18
		3.10	.252	1.99	1.09
		3.23	.245	1.82	1.18

[a] Schneidewind, Meyer and Frese, Landw. Jahrb., 35, 927 (1906). Analyses made with 10 per cent hydrochloric acid, except in the case of phosphoric acid, where complete analyses are given.

Chemical composition of the soils of Germany—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
OLDENBURG.[a]		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Marsh soils	1	2.23	0.25	4.34	1.66
	2	2.14	.21	4.24	1.41
	3	.73	.21	5.86	1.71
	4	.89	.18	6.57	1.81
	5	.62	.23	7.09	1.85
	6	.26	.12	.43	----------
	7	.17	.08	2.52	----------
	8	.45	.05	.10	----------
	9	.41	.13	.14	----------
	10	.43	.26	.50	----------
	11	.44	.15	3.28	----------
	12	.39	.11	3.28	----------
	13	.62	.05	.11	----------
	14	.44	.18	.19	----------
	15	.44	.11	.24	----------
	16	.38	.16	.28	----------
	17	.46	.10	----------	----------
	18	.33	.13	----------	----------
	19	.24	.10	.21	----------
	20	.62	.12	.95	----------
	21	.37	.11	.42	----------
	22	.38	.13	.39	----------
	23	.33	.09	.33	----------
	24	.33	.16	1.53	----------
	25	.82	.16	1.26	----------
	26	.46	.11	1.16	----------
	27	.57	.14	.78	----------
	28	.54	.18	.39	----------
	29	.32	.10	.69	----------
	30	.43	.12	2.40	----------
	31	.49	.12	.46	----------
	32	.55	.20	.46	----------
	33	.56	.19	.47	----------
	34	.60	.19	.49	----------
	35	1.00	.28	4.99	----------
	36	.18	.08	4.48	----------
	37	.39	.11	.52	----------
	38	.35	.10	.46	----------
Blauhandter Groden	----------	.59	.151	2.27	----------
Ellenserdammer Groden	----------	.66	.152	3.87	----------
Friedrich August Groden	----------	.68	.193	4.88	----------
Adelheids Groden	----------	.62	.235	5.16	----------
Peters Groden	----------	.56	.25	5.28	----------
BAVARIA AND WURTTEMBERG.[b]					
Moor soils	608	.091	.276	4.82	----------
	597	.077	.272	3.51	----------
	610	.099	.256	2.77	----------
	609	.088	.34	2.13	----------
	612	.046	.183	1.50	----------
	611	.056	.266	1.20	----------
	613	.060	.243	.921	----------
	232	----------	.185	2.85	----------
	233	.237	.211	1.19	----------
	234	.1265	.397	1.25	----------
	235	.067	.165	.471	----------
	69	.0754	----------	----------	----------
	248	.0761	.139	.529	----------
	223	.0611	.119	.387	----------
	219	.0669	.146	.681	----------
	243	.0738	.147	.506	----------
	246	.0665	.122	.338	----------
	224	.0565	.156	.454	----------
	451	.0517	.127	.459	----------
	242	.0638	.133	.557	----------
	241	.0588	.121	.331	----------
	249	.0478	.085	.61	----------
	452	.0645	.142	.341	----------
	453	.0682	.127	.254	----------
	222	.0496	.117	.397	----------
	454	----------	.107	.325	----------
	247	.0467	.129	.421	----------
	244	.0508	.094	.377	----------
	220	----------	.069	.168	----------

[a] Schucht, Jour. Landw., 53, p. 322 (1905). Maercker, Zusammensetzung und Düngerbedürfnis Oldenburg Marscherden und deren Bewirtschatung, Berlin, 1896.
[b] Vierteljahresschr. bayer. Landw.-Rat, 10, Ber. Arbeiten Moorkult. 1904.

Chemical composition of the soils of Germany—Continued.

Description and locality.	Original sample No.	Potash (K_2O).	Phosphoric acid (P_2O_5).	Lime (CaO).	Magnesia (MgO).
BAVARIA AND WURTTEMBERG—continued.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moor soils	221	....	0.094	0.535	....
	237	0.0365	.076	.368	....
	245	.0386	.106	.214	....
	239	.032	.093	.371	....
	240	.0307	.085	.516	....
	236	.028	.066	.344	....
	238	.0238	.061	.333	....
	580	.116	.097	.36	....
	581	.097	.098	.404	....
	593	.075	.125	.28	....
	594	.074	.151	.257	....
	592	.065	.106	.439	....
	585	.076	.152	.272	....
	589	.0586	.121	.217	....
	591	.0457	.135	.306	....
	595	.064	.114	.228	....
	577	.063	.18	.24	....
	586	.074	.153	.356	....
	578	....	.164	.29	....
	583	.056	.108	.289	....
	575	.050	.194	.32	....
	572	.061	.146	.312	....
	579	.047	.162	.336	....
	587	.0451	.117	.259	....
	576	.041	.129	.298	....
	574	.046	.127	.367	....
	588	.043	.113	.265	....
	584	.042	.088	.318	....
	590	.037	.092	.517	....
	582	.033	.096	.313	....
	573	.021	.121	.401	....
	544	.0794	.184	.383	....
	542	.0587	.152	.39	....
	1076	.0668	.259	.535	....
	547	.073	.206	.826	....
	540	.0629	.156	.89	....
	541	.0535	.119	.425	....
	536	....	.164	.419	....
	1074	.058	.217	.423	....
	1071	.063	.182	.58	....
	539	.0482	.158	1.02	....
	537	....	.106	.40	....
	538	.0473	.083	.615	....
	543	.039	.139	.825	....
	546	.0293	.074	2.73	....
	1073	.042	.20	.576	....
	1075	.054	.207	.078	....
	1072	.041	.177	.906	....
	545	....	.094	.742	....
Loess soils[a]	1	.15	.16	14.95	0.96
	2	.12	.13	14.10	1.20
	3	.13	.13	12.50	1.20
	4	.14	.18	16.76	Trace.
	5	.12	.19	10.26	.61
	6	.18	.14	12.20	Trace.
	7	.13	.11	16.40	.29
	8	.20	.15	17.80	.93
	9	....	....	47.00	.46
Middle-sandstone soils[b]	1	.06	.05	.09	.05
	2	.05	.04	.05	.04
	3	.06	.07	.17	.19
	4	.06	.08	.19	.14
	5	.03	.02	.02	.02
	6	.09	.09	.00	.27
	7	.19	.05	.014	.08
	8	.17	.18	.25	.09
	9	.13	.34	.52	.15
North German plain loess[c]	....	2.33	....	6.6	1.37
		2.47	....	.59	.25
		.81	....	.50	.17
		2.58	....	.80	.72
		2.57	....	.43	.70
Highland	....	.109	.115	.064	.238
		.41	.06	.29	.64
		.026	.088	.072	.075
		.102	.03	.242	.161

[a] Halenke, Kling and Engels, Vierteljahressch. bayer. Landw.-Rat, 10, 447 (1905).
[b] Blanck, Landw. Vers.-Sta., 65, 161 (1906).
[c] Burguy, Über die Bödenverhältnisse des norddeutschen Flachlandes in ihrer Beziehung zum geologischen Aufbau desselben. Inaug.-Diss. Berlin, 1899.

Appendix C.

WATER SOLUBLE CONSTITUENTS OF SOIL.

Locality, Salem, N. J. Soil type, Norfolk sand. Crop, wheat.

[Yield of crop, good.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
March 10	0-12	13.2	12	5	12
	12-24	11.5	7	5	16
June 8	1-24	4.3	4	14	13
June 13	1-24	4.6	5	13	17
June 19	1-24	9.6	2	14	24

Locality, Salem, N. J. Soil type, Norfolk sand. Crop, wheat.

[Yield of crop, poor.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
April 3	0-12	12	11	5	32
	12-24	12	10	3	22
June 16	1-24	9.3	4	29	20

Locality, Salem, N. J. Soil type, Sassafras loam. Crop, wheat.

[Yield of crop, medium.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
March 10	0-12	23.2	19	10	8
	12-24	21.6	11	10	14
March 14	0-12	22.3	18	8	18
	12-24	20.2	15	12	21
	24-36	20.3	18	17	16
March 20	0-12	19.3	7	10	21
	12-24	18.6	4	11	21
	24-36	12.6	5	12	21
June 16	1-24	22.5	4	24	23

Locality, Salem, N. J. Soil type, Sassafras loam. Crop, grass.

[Condition of crop, medium.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
March 10	0-12	25	13	28	18
	12-24	23.8	7	26	13
	24-36	19.9	16	8	15
March 14	0-12	25.8	21	12	21
	12-24	23.1	8	12	15
	24-36	21.8	9	15	21
March 31	0-12	23	11	23	43
	12-24	21.6	8	20	34
April 2	0-12	24.8	8	16	41
	12-24	24	6	21	38
	24-36	21.4	3	11	25

Locality, Salem, N. J. Soil, type, Sassafras loam. Crop, wheat.

[Yield of crop, good.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
March 17	0–12	22	8	6	10
	12–24	18.1	8	15	14
March 17	0–12	18.3	10	15	Lost.
	12–24	18.1	9	24	25
March 24	0–12	24.7	14	12	30
	12–24	22.3	8	11	38
March 26	0–12	23.4	4	16	16
	12–24	23.9	12	16	20
	24–36	22.4	8	3	21
April 2	0–12	25.6	8	16	30
	12–24	24.4	8	17	47
	24–36	21.6	8	11	38
June 5	0–12	5.2	14	51	23
	12–24	8	15	55	32
June 8	1–24	10.6	2	20	13
June 11	1–24	15.5	6	26	14
June 13	1–24	8.2	6	19	22
June 16	1–24	15	5	21	19
June 17	1–24	10.6	7	63	17

Locality, Salem, N. J. Soil type, Sassafras loam. Crop, clover.

[Yield of crop, medium.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
March 20	0–12	20.8	5	15	32
	12–24	20.2	5	15	27
	24–36	18.6	5	12	36
March 26	0–12	26.8	9	31	20
	12–24	22.9	8	20	18
	24–36	22.5	4	14	20
June 6	0–12	8.1	8	16	17
	12–24	12.7	9	18	20

Locality, St. Marys, Md. Soil type, Leonardtown loam. Crop, wheat.

[Yield of crop, good.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
April 27	0–12	21.8	5	10	12
	12–24	21.3	4	7	10
April 29	0–12	22.2	8	15	52
	12–24	21.8	4	11	38
May 1	0–12	22.4	7	14	23
	12–24	21.8	7	8	30
May 1	0–12	17	5	16	25
	12–24	21	5	7	19
May 9	0–12	15	13	34	28
	12–24	15.9	9	17	26
May 15	0–12	14.2	3	14	24
	12–24	19.9	4	13	25
August 14	0–24	15	6	11	13
August 15	0–24	15.7	5	3	17
August 15	0–24	16.4	8	15	15

Locality, St. Marys, Md. Soil type, Leonardtown loam. Crop, wheat.

[Yield of crop, poor.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
May 14	0-12	14.7	5	8	35
	12-24	19.9	4	4	30
May 23	0-12	7.8	4	7	22
	12-24	14.9	4	11	23
August 14	0-24	16	4	4	16
August 15	0-24	19.5	6	4	13

Locality, St. Marys, Md. Soil type, Leonardtown loam. Crop, corn.

[Yield of crop, good.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
May 8	0-12	18.2	9	12	29
	12-24	18.9	10	7	26
May 18	0-12	18.2	3	24	38
	12-24	18.8	6	19	28
August 8	0-24	17.5	7	30	18

Locality, St. Marys, Md. Soil type, Leonardtown loam. Crop, corn.

[Yield of crop, poor.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
May 23	0-12	16.6	5	12	22
	12-24	17.4	6	8	22
August 8	0-24	19.9	9	25	20
August 15	0-24	21.6	7	15	13

Locality, Statesville, N. C. Soil type, Cecil clay. Crop, clover.

[Yield of crop, good.]

Date.	Depth.	Moisture content.	Parts per million of oven-dried soil.		
			Phosphoric acid (PO_4).	Calcium (Ca).	Potassium (K).
	Inches.	*Per cent.*			
March 17	0-12	19.6	7	....	5
	12-24	20.9	13	....	6
March 17	0-12	24.7	16	....	5
	12-24	35.1	18	....	7
	24-36	30.7	22	....	10
March 17	0-12	20.2	10	....	5
	12-24	21.4	12	....	6
August 7	0-17	18.8	2	....	34
	0-24	20	24	....	....

COMMERCIAL FERTILIZERS AND FERTILIZER INSPECTION.

By Dr. Milton Whitney,
Chief of Bureau of Soils, United States Department of Agriculture.

It has been shown in the discussion of "Crop Yields and Soil Composition" that there are three principal methods of control of soil fertility, a subject which is the very foundation of the material wealth of this nation and of its position among the countries of the world; these are cultivation, rotation of crops, and fertilization. Of these, the first two are in the hands of the farmer himself, and require only knowledge, intelligence, and skill in manipulation. Fertilizing materials, however, have, to a very large extent, to be gathered for him from different parts of the world and manipulated before they are ready to be applied to the land.

It was early found that unscrupulous manufacturers were ready to, and actually did, perpetrate gross frauds upon the farmers by selling worthless material for exorbitant prices.[a] The first practical method devised to meet the situation in this country was a voluntary agreement or understanding between the manufacturers, dealers, and farmers, to submit for analysis samples of all brands offered for sale or purchased in a State to some competent chemist in the agricultural society, state department of agriculture, or experiment station, as a final arbiter. Such an agreement was entered into in Connecticut in 1876, and the reasons for it and terms of agreement are given in an appendix of this article.[b] Subsequent to this, most of the States passed very strict and comprehensive fertilizer-control laws, which have worked admirably in preventing frauds, to the advantage alike of manufacturers and farmers. Broadly speaking, this regulation has been vested in the state experiment stations in the Northern States and in the state departments of agriculture in the Southern States, and is based upon the general policy of police regulations for the public good. Generally speaking, also, a fee is exacted from the manufacturers in the Northern States, based upon the number of valuable plant-food constituents (phosphoric acid, nitrogen, and potash) claimed to be present in the fertilizers, while in the Southern States,

[a] See transactions of the Connecticut State Agricultural Society for the year 1859, p. 41.

[b] Previous to this, however, the State passed a law making it mandatory for all manufacturers or dealers to affix a guaranteed analysis to each package of fertilizer, with certain exceptions, and authorizing the president of the State Agricultural Society to have analyses made at his discretion, and prosecute for frauds, under his judgment.

besides a fee for registration of brands, a tax of so much per ton is exacted, thus providing a considerable revenue for the State.

On account of the interstate character of the fertilizer trade, it has not been possible for the state authorities to maintain a factory inspection, and they have had to rely upon the guaranty of the manufacturer as to the nature of the material which has been put into the fertilizer (which statement is generally considered confidential), and upon their own analysis of samples picked up at random in the open market. This has, from the first, been recognized as a weak point in the present fertilizer-control system. The analysis is recognized as merely a commercial valuation, with little or no connection with the agricultural values of the fertilizer.

At first the inspecting officers determined merely the total amount of nitrogen, the water soluble potash, and the water and citric acid soluble phosphoric acid, and allowed a liberal value for each of these ingredients when contained in a mixture, based upon the assumption that only high-grade goods had been used by the manufacturer. The tendency in quite recent years, however, is for the inspecting officers to make more complete analyses, in an effort to show more about the origin of the materials in the mixtures. It is obviously impossible from any analysis, however complete, or from any microscopical investigation to determine with accuracy the character of the material that has been used, and the only method by which such information could be reliably placed before the purchasers would be by factory inspection, in which the kind and amount of material used in the mixture would be certified on the package and vouched for by the impartial inspector.

The reason for the beneficial effects of fertilizers has long been held[a] to be due to the supply of mineral plant food to the soil in a more soluble or available form than is found in soils of low productivity. That this is not the most important function of fertilizers has long been suspected by thoughtful men, who could not reconcile many well-known and obvious facts with this plant-food theory. Nevertheless, it was not until the investigations of the Bureau of Soils into the chemistry of the mineral portion of the soil, showing the remarkable constancy of composition of the soil moisture and demonstrating the reasons for this, that we were able to say conclusively that this is not the chief nor most important function of fertilizers. Not until the researches on the chemistry on organic matter in the soil had revealed the presence of toxic organic bodies, resulting from the growth of crops, and the analogy was seen with the metabolic processes of the animal body, and the processes for the elimination of the waste products so formed, did rational reasons for cultivation, crop rotation, and fertilizers become apparent, among others being the elimination of harmful waste products and the preservation of proper sanitary conditions in the soil. It was then evident also why the ordinary chemical analysis of the soil had failed to reveal the ferti-

[a] The use of commercial fertilizers is not old. The first lot of natural guano was imported into England in 1840, and nitrate of soda about 1830. The potash deposits of Germany were first worked in 1862. The phosphate deposits in South Carolina in 1868. Phosphates were discovered in Florida in 1888, and in Tennessee in 1894.

lizer requirements, and why different substances, having the same chemical ingredients, often have very different effects on soils and crops.

A great fertilizer trade, estimated at from $80,000,000 to $100,000,000, or approximately 1 per cent of the total value of our agricultural products, has been built up on the supposition that soils wear out and become exhausted of their available mineral food, and that it is necessary, in order to maintain the fertility of our soils, to bring nitrates from Chile, potash from Germany, and phosphates from certain deposits in this country in order to return to the soil the equivalent of what is removed by our crops.

That it is the material and not the element which determines the possible agricultural value of the fertilizer is becoming more and more evident every day. Most of the States prohibit the incorporation into commercial fertilizers of such substances as ground leather, horn shavings, feathers, hair, wool waste, or muck, although these are highly nitrogenous, because it is the general belief that they are ineffective when applied to the soil. It is not believed by competent persons that nitrate of soda, sulphate of ammonia, and the various organic forms of nitrogen commonly used in fertilizers are equally effective on all soils, crops, and in all seasons. Indeed, we have undoubted evidence that they may differ widely, and yet we apply them indiscriminately and without certain knowledge of what we are using in our commercial fertilizers. The same way with the materials furnishing phosphoric acid and, to a less extent, with potash. It is true that the inspecting officers of the various States are making more complete analyses in order to determine more nearly the nature of the materials in the mixture, to verify the statement of the manufacturers, but it is admitted that this is only approximate and incomplete. There is nothing accomplished by the present system of inspection which the factory inspection would not show much better, besides giving the certain information that we are purchasing nitrogen in the form of nitrate of soda, sulphate of ammonia, cotton-seed meal, tankage, and other forms, which information may be the means of insuring success and of establishing a rational system of fertilization which up to this time has not prevailed in this country. In the nature of the case the States can not maintain a general factory inspection, but the Federal Government can, as they do in meat inspection.[a] The chief objection to federal inspection has been that it would remove certain sources of revenue from the States, but there seems no valid reason why even with federal inspection the States can not still exact a fee from dealers and a tonnage tax on the amount sold in the State.

It has been stated above that there is no rational system of fertilization in general use in this country, and in this respect the United States appears to be far behind some European countries. We have, indeed, a general idea of the form of fertilizer material adapted to some of our soils and crops and some idea of the relation of soil conditions and climatic conditions to fertilizer action, but these ideas are not based upon exact facts and are not practically applied by our fertilizer manufacturers or farmers.

[a] The Twelfth Census gives 422 fertilizer manufacturers in the United States.

The advice of our agricultural chemists and agronomists is almost universal that farmers should test their soils by plot experiments to determine the most efficient forms and combinations of fertilizers. Such experiments are costly and take time, and results vary with different seasons. Such of our experiment stations as have carried on these fertilizer tests hesitate to draw conclusions with less than an average of ten years. One of the most recent of the standard books on fertilizers[a] asserts in the most cautious way and with many qualifications that corn is particularly responsive to phosphates, cereal crops to nitrates, grasses and clovers to phosphoric acid and potash, beets and carrots to nitrogen, potatoes and sweet potatoes to potash, and truck crops to nitrogen, and yet with only this meager information, not pretending to be exact or invariable, we find a multitude of brands on the market, many of them being prepared and recommended for special crops. One has but to look up the reports of the departments of agriculture and state experiment stations charged with the inspection of fertilizer materials to see the absolute lack of system which prevails in the fertilizer trade. The tendency in this country seems to be to increase the number of special brands for special crops, but there is an absolute lack of uniformity, even in the elementary composition of these special brands.

As a rule, the fertilizer formulæ are simpler and more uniform in the South than in the North, and there are also a less number of special brands for special crops. For example, there are very few fertilizers for special crops offered in the States of Alabama and Georgia. In North Carolina about 28 per cent of the whole number of brands of fertilizers sold in the State are recommended for special crops. In Connecticut 45 per cent of the whole number of brands sold are special brands for special crops. In the State of Georgia there were 1,822 brands inspected, analyzed, and placed upon the market for sale in 1908. Of these, 1,260 brands contained two or more of the plant-food elements (phosphoric acid and nitrogen or potash) in 106 different combinations, as shown on the guaranties; 1,143 of these brands, or 90 per cent, contained 6 or more identical guaranties covered by 26 combinations; there were 255 brands, or 27 per cent, of the complete fertilizers which contained 10 per cent of phosphoric acid, 2 per cent of ammonia, and 2 per cent of potash. There were 242 brands, or 26 per cent, which contained 8 per cent of phosphoric acid, 2 per cent of ammonia, and 2 per cent of potash. If these brands differ in the material of which they are composed, the farmers should know it to enable them to make a more intelligent selection for their particular soils and crops, but there is no way in which they can find out whether the brands differ or not. It is also to the interest of the manufacturer to have this known. The brands undoubtedly differ in effectiveness by reason of the materials which they contain, and we are sadly neglecting our opportunities of developing agricultural practice by failure to know the material these fertilizers actually contain. Of the 33 special brands for tobacco placed on sale in the State of Connecticut, phosphoric acid ranges from 3 to 9 per cent, ammonia from 2 to 7¼ per cent, and potash from

[a] Fertilizers, by Edward B. Voorhees, 1902.

2 to 11 per cent; there are 24 different combinations in the 33 brands issued for this very limited crop in Connecticut. Instances of this kind could be multiplied almost indefinitely, and it is considered best to submit with this report an appendix giving a very complete analysis of the figures relating to the fertilizers on sale in three of the Southern States (Alabama, Georgia, and North Carolina) where the fertilizer control is under the state departments of agriculture, and in three of the Northern States (Maine, Massachusetts, and Connecticut) where the fertilizer control is vested in the state experiment stations.

Most of the States regulate by law, or by executive order under authority of law, material which may or may not be used in commercial fertilizers and the words which may be printed or stamped on the brands. Thus the State of Georgia prohibits the use of the word "standard" in connection with a brand containing less than the commercial equivalent of 8 per cent of phosphoric acid, 2 per cent of ammonia, and 2 per cent of potash; and of the words "high grade" on any fertilizer containing less than the commercial equivalent of 10 per cent phosphoric acid, 2 per cent ammonia, and 2 per cent potash, although both of these combinations are far below the combinations recommended by the state department of agriculture for crops.

It is the general belief at the present time that a fertilizer for tobacco should be rich in potash, and that for cigar tobacco the potash should be in the form of carbonate, yet we find in Connecticut special brands for tobacco with from 1 to 3 per cent of potash, and so far as the evidence permits one to judge the potash in the majority of brands is not in the form of carbonate. It would seem that it would be possible by law, and a protection to the farmers, to prohibit the use of the word "tobacco" on a brand of fertilizer containing less than 6 per cent of potash, to be contained in the form of carbonate only.

It is the general belief that potatoes require fertilizers rich in potash, and that it is better to have the potash in the form of sulphate, yet we find brands of special fertilizers for potatoes offered for sale in Maine with only 2 and 3 per cent of this ingredient. In this case also it should be possible under the law, and a protection to the farmers, to prohibit the use of the word "potatoes" on any special brand for potatoes with less than a minimum of, say, 6 per cent of potash, and this in the form of sulphate only.

It is believed and taught by the Maine Experiment Station [a] that nitrogen for potatoes should be in the form of nitrate nitrogen, and yet even in that State the principle is not enforced by law, and the nitrogen supply in special fertilizer brands for potatoes is of such form as may be determined by the manufacturer. It is the general belief that sugar beets require a fertilizer rich in potash, and that it is best to have this in the form of chloride or muriate; but no particular attention seems to be paid to this in the preparation of special brands, and farmers do not know what materials they are purchasing, and can not know with the best system of inspection which is being maintained by any State.

Instances could be multiplied indefinitely where our practice does not conform even to our present best knowledge.

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[a] Bul. 153, Maine Agr. Expt. Sta., March, 1908, p. 105.

The only conclusions that can be arrived at from the study of this material are—

That the form of inspection that has prevailed in the past is inadequate for the growing needs of the farmer for more definite and more explicit information in regard to the composition of the materials going into the commercial fertilizers, and that proper inspection can only be made by the Federal Government on account of the interstate character of the fertilizer trade.

That there is no rational system of fertilization in this country, and although we have an enormous trade in fertilizing material, it is absolutely necessary that the whole question of the effective composition of fertilizers be investigated in order to work out the most effective and most efficient system of fertilization.

And that our knowledge of the requirements of special fertilizers for special soils and crops is wholly inadequate to the needs of our people, and the subject requires a thorough and complete investigation in order that we may use our valuable fertilizing materials to the best advantage, making this method of the control of soil fertility of the higest efficiency. The time has come when we begin to know something of the true principles of fertilizer action and when the methods of investigation are adequate to solve this very intricate problem, which has grown to enormous proportions upon no adequate knowledge or basic efforts to insure the success which we should reasonably expect.

Appendix A.

EXTRACTS FROM OFFICIAL REPORTS AND STANDARD BOOKS ON FERTILIZERS.

The following extracts do not pretend to be a complete résumé of the literature on fertilizers, as the subject is very voluminous, but only to give a few striking statements from recognized authorities on the points which have been made in the preceding report:

In its work in connection with commercial fertilizers, in detecting and driving out frauds, placing the trade on a rational basis, encouraging honest manufacturers and sellers, and teachiug farmers how to select their fertilizers wisely and use them with profit, its [the experiment station's] usefulness can not be overestimated. (First Annual Report, Conn. Agr. Expt. Sta., 1876, prefatory note, p. 3.)

The means adopted by the station to regulate the sale of fertilizers in the State has been explained quite fully in Circular No. 4 of the station. * * *

The plan is substantially the same as has, with various modifications of detail, come into quite general usage in Germany and other European countries. The essential features are:

First. An agreement made with the station by dealers in fertilizers to sell their wares by guaranteed analysis, the verification of the analysis being left to the station; and

Second. A provision whereby purchasers may have samples of the articles they buy analyzed by the station at small cost or for nothing.

In order to preclude all chance for mistake or cavil as to the precise terms of the arrangement referred to a form of agreement has been signed by the dealers who desired to place their wares, as sold in the State, under the supervision of the station.

The form referred to is the result of deliberations of a large meeting of manufacturers, sellers, and consumers of fertilizers held at the station and of consultation with the advisory committee and with other parties interested. It is as follows:

BLANK B.

______ hereby agree with the Connecticut Agricultural Experiment Station, as represented by its directors, that all fertilizers offered for sale in the State of Connecticut by ______ or by ______ authorized agents, at any price above $15 per ton, except crude fish scrap, shall be placed under its supervision in the following manner:

1. ______ hereby agree that all fertilizers above described shall be guaranteed to contain certain minimum percentages of one or more of the following ingredients:

Nitrogen.
Phosphoric acid; soluble.
Phosphoric acid; reverted.
Phosphoric acid; insoluble.
Potash.
Sulphuric acid; chlorine.

2. ______ also agree that the above guarantee shall be always subject to verification by analyses made at the stations.

3. ______ also agree that all fertilizers above described shall be at all times open to the inspection of the station, as represented by its director, chemists, or any member of its advisory committee. * * *

The signer of this agreement is not expected to specify in this blank the composition of the wares he sells, but he does bind himself to fulfill the requirements of the state law, by accompanying every package of fertilizer sold with a plain statement of the analysis, using the above terms, and to guarantee the article to be equal to the analysis.

In brief, this statement binds the signer simply to state what he sells and guarantees what he states, the verification of the statement being left to the official analysis of the station. With the fulfillment of this guarantee the responsibility of the seller will naturally end. The station provides that buyers who wish to determine whether the articles they purchase are equal to the guarantee, may have control analyses made at little or no expense. It is believed that no simpler nor more efficient way can be devised to place the trade in fertilizers on a more secure basis, insure confidence, and benefit all concerned. (First Annual Report, Conn. Agr. Expt. Sta., 1876, pp. 14–16.)

The question as to which is the most serviceable and best fertilizer is like the question, Which is the best and most serviceable medicine?—impossible to answer. All depends on the patient, on what ails him, and on how he is being treated otherwise.

The experiment station might be compared to a sanitary engineer, but not to a practicing physician. We are unable to prescribe for land. The only way is for the practical farmer to make trials on his land with fertilizers or fertilizing chemicals which he knows are of good quantity (quality?) and study the effects. * * *

There is a choice also in respect to action on the crop. This will depend somewhat on the character of your soil and can only be learned by experience. One fertilizer will appear to be best one year or on some crops and land, and another season, owing to the different weather, wet or drought, or on other land or plants another kind of fertilizer will give the best results. I should try a fertilizer that would give me a good percentage of nitrogen, soluble phosphoric acid and potash, for the least money.

We can give no formula for an onion manure. The food which the onion requires is the same that all other crops require. If it requires any special proportions of fertilizing ingredients, neither we nor anyone else can positively say what that is. Probably a fertilizer having about the composition of the "special" onion, potato, tobacco, or corn manures would be as profitable a fertilizer as you could apply to the onion. * * *

It is a fact of common farm experience that nitrogenous manures differ widely in their efficiency. Nitrate of soda, for example, often has a visible effect on grass land within ten days after sowing; dried blood requires a longer time to affect the color or growth of grass, while an application of leather or hair may never show the slightest effect. * * *

A considerable number of manufacturing wastes, rich in nitrogen, but differing greatly in their values as plant foods, are now on the market, and their use is urged upon manufacturers of mixed fertilizers. In general, such of these waste products as are agriculturally of least value are also least expensive, and therefore the temptation to use them in manufactured goods is to some very strong.

It is highly desirable to know in the first place how these nitrogenous wastes compare with each other, and with some standard, such as nitrate of soda in availability and various experiments have already accomplished something in this direction. In the next place it is important, either to be able to identify these various "ammoniates" and mixed fertilizers or else to have some means of distinguishing in such fertilizers between available and inert nitrogen; some measure of its availability. Unfortunately it has hitherto been difficult or impossible to identify with certainty most of the inferior ammoniates, either by inspection or by ordinary chemical tests. The treatment with acid during the process of manufacture, the grinding, and the mixture with phosphatic material and potash salts so alters the structure and appearance that in many cases the microscope fails to identify anything and chemical tests are not generally applicable. (Annual Report Conn. Agr. Expt. Sta., 1885, pp. 110–115.)

We have reason to believe from extended observations and experience in the field that hundreds of thousands of dollars are annually wasted by farmers in the lavish and injudicious application of fertilizers on cotton. The author shows that the different forms of phosphates and the different materials used to supply nitrates vary greatly in their efficiency. (Fertilizers for Cotton, J. M. McBryde, Farmers' Bulletin 14, 1894, p. 7.)

"The most satisfactory, and, indeed, usually the only method," says Armsby, "by which we can at present determine the needs of a soil is to ask the question of the soil itself by growing a crop upon it with different kinds of fertilizers and noting the result. Such soil tests with fertilizers have in many cases given results of which immediate practical value for the locality in which they were undertaken."

Many materials containing the essential elements are practically worthless as sources of plant food because the form it not right. * * * All materials containing organic nitrogen are valuable in proportion to their rapidity of decay or change. * * * Thus organic nitrogen differs in availability not only according to the kind of material which supplied it, but upon the treatment it receives. * * * The phosphoric acid in natural or untreated phosphates is insoluble in water and not readily available to plants; that is, the rate of availability depends largely upon the rapidity with which the substance rots or decays, and the rate of decay again depends upon the character of the substance with which the phosphate is associated. * * * Potash may exist in a number of forms, though chiefly as chlorids, or muriates, in which case the potash is combined with chlorin; and as sulphates, in which the potash is combined with sulphuric acid. With potash, however, the form does not exert so great an influence upon availibility as is the case with nitrogen and phosphoric acid. All forms are freely soluble in water, and are believed to be nearly if not quite equally available as food. The form of potash has, however, an important influence upon the quality of certain crops, due rather to the constituents with which the potash is associated than to the potash itself. * * * The character or form of the material used must therefore be carefully considered in the use of manure. * * * All manufacturered products or brands of fertilizers are made up of a mixture of the various kinds and forms of fertilizing materials just described, and the differences that exist in the brands of different manufacturers are due both to differences in the character and to the variations in proportions of the materials used to form the different brands; that is, while all manufacturers must go to the sources of supply indicated, they may select either good or poor products and may vary the proportions of the different materials used.

The difference between a good brand of fertilizer and a poor one lies not so much in differences that may exist in the total amount of plant food contained in it as in the quality of the materials of which it is made. (Commercial Fertilizers, Farmers' Bulletin 44, Edward B. Voorhees, 1896.)

The following extracts are from Fertilizers, by Edward B. Voorhees, originally published in 1898, with a fourth edition in 1902:

Preface: There is no question as to the desirability of the use of commercial fertilizers on most farms, though the methods now generally practiced are such as to indicate the very great need of a better understanding of what the functions of a fertilizer are, of the terms used to express their composition and value, of the kind that shall be used, and the time and method of application for the different crops under the varying conditions that exist. * * *

The author appreciates keenly his limitations, owing to the lack of definite knowledge on many vital points; yet it seems that at this time, when the investigations of the experiment stations are beginning to be regarded as important educational factors, and when these institutions are more than ever prepared to study the fundamental principles which underlie the various processes involved in plant nutrition, the practical man should have a clear understanding of what is now known, in order that he may be prepared to accept and use that better knowledge which will undoubtedly be provided for him in the near future.

Page 49: It will be observed from the foregoing brief description of the chief sources of organic forms of nitrogen that a very wide variation occurs both in the composition or content of nitrogen in these products and in the availability of their nitrogen, or rapidity with which, under similar conditions, it is given up to plants. The fact that a substance contains nitrogen in considerable amounts and in an organic form, then, is not a sufficient guide as to its usefulness.

Pages 54–57: The practical point, and the one of prime importance to the farmer, is, then, to know how to estimate the relative value or usefulness of these different products, what is the rate of availibility as compared with nitrate, and thus the relative advantage of purchasing the one or the other at the ruling market prices. Relative values, however, can not be assigned as yet, though careful studies of the problem have been made, chiefly by what are known as "vegetation tests," that is, tests which show the actual amounts of nitrogen that plants can obtain from nitrogenous products of different kinds when they are grown under known and controlled conditions. The results so far obtained, while only serving as a guide, indicate that when nitrate is rated at 100 per cent, blood and cotton-seed meal are about 70 per cent, dried and ground fish and hoof meal 65 per cent, bone and tankage 60 per cent, and leather, ground horn, and wool waste range from as low as 2 per cent to as high as 30 per cent. These figures furnish a fair basis for comparing the different materials when used for the same purpose or under the same conditions. If, for example, the increased yield of oats due to the application of nitrate of soda is 1,000 pounds, the yield from blood and cotton-seed meal would be 700 pounds, the yield from dried ground fish and hoof meal would be 650 pounds, from bone and tankage 600 pounds, and from leather, ground horn, and wool waste, from 20 to 300 pounds.

These figures alone are, however, not a sufficient guide as to the kinds to buy under all conditions, since the usefulness of the different forms are again dependent upon such other conditions as the kind of crop, the season, and the object of the application. * * * In the making up of fertilizers, all of these considerations should be carefully balanced, and it is the practice on the part of many manufacturers to use a part of each of the three forms, so that a continuous feeding of the plant may be insured. Therefore, while the fact remains that fertilizers containing only the one form may not be the poorest, the chances are that those which contain all forms are likely to give more satisfactory results.

Pages 92–94: It [potash] is, however, a very necessary constituent of fertilizers, being absolutely essential for those intended for light, sandy soils and for peaty meadow lands, as well as for certain potash-consuming crops, as potatoes, tobacco, and roots, since these soils are very deficient in this element, and the plants mentioned require it in larger proportions than do others. * * *

Potash, as has already been stated in the discussion of phosphoric acid and nitrogen, exists in various forms, but it differs from the other elements in that its chemical form or combination seems to exert but relatively little influence upon the availability of the constituent. For example, it may be in a form of muriate or chlorid, of a sulphate or of a carbonate, and while there is a difference in the diffusibility of these different compounds—that is, a difference in the rate at which they will distribute in the soil before becoming fixed—there seems to be very little difference in the rate of the absorption of the potash by the plant. Nevertheless, the form of potash must be observed, because of the possible influence that the substances with which it combines may exert in reducing the marketable quality of the crop to which it is applied. This influence has been very distinctly observed, particularly in the growing of tobacco, sugar beets, and potatoes, and it has been shown that the potash in the form of a chlorid (or muriate) does exert a very deleterious effect, especially on tobacco.

Pages 129–130: In the purchase of mixtures consumers should demand that they be accompanied by a guaranty, because they are unable to determine the kind and proportion of the different materials entering into the mixture, either by its appearance, weight, or smell. In mixing, too, an opportunity is afforded for disguising poor forms of the constituents, particularly nitrogen; that is, in a mixture of nitrogeneous materials, potash salts and superphosphates, it would be a difficult matter to determine, by mere physical inspection, the proportion of the nitrogen which had been supplied in the form of horn meal and of blood, and the statement of the manufacturer on this point would be valuable in proportion to his reliability.

Page 149: An analysis may show simply the total amount of the constituent. This is not a sufficient guide as to the value of the mixture, for while it is not possible to indicate absolutely by analysis whether the organic nitrogen, for example, is derived from blood (which is one of the best forms), or from horn meal (one of the poorer forms), it is possible to show whether the nitrogen is derived from nitrate of from ammonia; whether the phosphoric acid is derived from a superphosphate or a phosphate, and whether the potash present is in the form of a sulphate or of a muriate. A high-grade or a low-grade fertilizer, for example, may be distinctly indicated by the analysis, since it is of a high grade if the three forms of nitrogen are present, if the total phosphoric acid is chiefly soluble in water, and if the poash has been derived from a sulphate or from a muriate.

Page 152: It is obvious, from what has been already pointed out, that the value of a fertilizer to the farmer depends not so much upon what is paid for it as upon the character of the material used to make it.

Page 175: A ton of wheat at $1 per bushel, will bring $33.33. Its sale removes from the farm 38 pounds of nitrogen, 19 of phosphoric acid, and 13 of potash. At prevailing prices for these constituents it would cost $6.50 to return them to the farm.

Pages 158–161: It will be observed that the schedule gives the cost per pound of the different forms of nitrogen and of high-grade organic nitrogenous materials; of nitrogen and phosphoric acid in ground bone and tankage; or available phosphoric acid in superphosphates, and of the actual potash in potash salts, and is a useful guide also in showing that the nitrogen, phosphoric acid, and potash contained in these materials can be purchased in ton lots for the prices mentioned. The valuation of mixed fertilizers, obtained by the use of this schedule, are entirely commercial; they are not intended to indicate even a possible agricultural value. * * *

Third. The chemical analysis does not show absolutely the sources of the materials, and thus it is difficult to place a true commercial value upon a mixture. This is especially true of organic nitrogen, derived from different materials, a uniform value is placed upon the total nitrogen found, whether it is derived from the best forms, as dried blood and dried meat, or whether derived from horn meal, ground leather, or other low-grade forms of nitrogenous materials. This encourages the use of low-grade products by unscrupulous manufacturers to the real detriment of the trade as a whole. * * *

Fourth. Any system of comparison of brands must leave a great deal to the judgment of the purchaser. He must interpret for himself whether he would rather that his phosphoric acid were derived from one source or another.

Page 167: The primary object in the use of a commercial fertilizer is to receive a profit from the increase in the yield of crops from the land to which it is applied; and this may be derived either from the immediate crop or from the larger yield of a number of crops. That the greatest immediate and prospective profit may be gained, a wide knowledge of conditions which have either a direct or indirect bearing upon the result is essential.

In fact, the controlling conditions surrounding the matter are so numerous and so various that it is impossible, with our present knowledge, to lay down positive rules for our guidance. At best, only suggestions can be offered.

Page 172: It must be remembered, then, that only general rules apply in the use of fertilizers upon soils of different classes, and that they are modified by both the chemical composition and the mechanical condition of the soil. The best use of a fertilizer—that is, the greatest proportionate return of plant food in the crop, all things considered—is obtained from its application upon soils that possess "condition" or that are well cultivated or managed. Full returns can not be expected when they are applied upon soils that are too wet or too dry, too porous or too compact, or too coarse or too fine. It is important that even the best soils should be properly prepared, and it is infinitely more important that those which possess poor mechanical condition should be improved in this respect, before large expenditures are made for fertilizers.

Pages 182–185: The one system of fertilization which has perhaps received the most attention, doubtless largely because one of the first presented, and in a very attractive manner, is the system advocated by the celebrated French scientist, George Ville. This system, while not to be depended upon absolutely, suggests lines of practice, which under proper restrictions may be of very great service. In brief, this method assumes that plants may be, so far as their fertilization is concerned, divided into three distinct groups. One group is specifically benefited by nitrogenous fertilization, the second by phosphatic, and the third by potassic; that is, in each class or group, one element more than any other rules or dominates the growth of that group, and hence each particular element should be applied in excess to the class of plants for which it is dominant. In this system it is asserted that nitrogen is the dominant ingredient for wheat, rye, oats, barley, meadow grass, and beet crops. Phosphoric acid is the dominant fertilizer ingredient for turnips, Swedes, Indian corn (maize), sorghum and sugar cane; and potash is the dominant or ruling element for peas, beans, clover, vetches, flax, and potatoes. It must be understood that this system advocates only single elements, for the others are quite as important up to a certain point, beyond which they do not exercise a controlling influence in the manures for the crops for the three classes. This special or dominating element is used in greater proportion than the others, and if soils are in a high state of cultivation, or have been manured with natural products, as stable manure, they may be used singly to force a maximum growth of the crop * * *.

Another system which has been urged, notably by German scientists, is based upon the fact that the mineral constituents, phosphoric acid and potash, form fixed compounds in the soil, and are, therefore, not likely to be leached out, provided the land is continuously cropped. They remain in the soil until used by growing plants, while the nitrogen, on the other hand, since it forms no fixed compounds and is perfectly soluble when in a form useful to plants, is liable to loss from leaching. Furthermore, the mineral elements are relatively cheap, while the nitrogen is relatively expensive, and thus that the economical use of this expensive element, nitrogen, is dependent to a large degree upon the abundance of the mineral elements in the soil. It is therefore advocated that for all crops and for all soils that are in a good state of cultivation, a reasonable excess of phosphoric acid and potash be applied, sufficient to more than satisfy the maximum needs of any crop, and that the nitrogen be applied in active forms, as nitrate of ammonia, and in such quantities and at such times as will insure the minimum loss of the element and the maximum development of the plant.

Page 186: Another system of fertilization is based upon the theory that the different plants should be provided with the essential elements in the proportions in which they exist in the plants, as shown by chemical analysis. Different formulas are, therefore, recommended for each crop, the constituents of which are so proportionate as to reach its full needs. This method, if care is taken to supply an abundance of all of the necessary constituents, may result in a complete though, perhaps, not an economical feeding of the plant, since it assumes that a plant which contains a larger amount of one constituent than of another requires more of that constituent in the fertilizer than of the others. It does not take into consideration the fact that the plant which contains a larger amount of one element than another may possess a greater power of acquiring it than one which contains a smaller amount.

Pages 189–190: The most expensive and irrational system of all, and one more commonly practiced than any other in general farming, may be termed that "hit or miss" system; if a "hit" is made there is a profit, if a "miss" the loss is trifling. In this system, no special thought is given to the character of the crop or its needs. If the farmer can afford it, he purchases a fertilizer, without regard to its composition, and applies it in very small amounts. If it happens to contain that element which is particularly needed for the plant to which it is applied, a profit is secured. In too many cases, however, the constituents added are already in abundance in the soil, or so little of the fertilizer is used as to preclude any profit.

Page 193: The lacking element can not be fully determined, except by direct experiments by the farmer himself. That is, no general principle can be depended on as an absolute guide. He should learn whether his soil is deficient in any of the elements, and, if so, which one should be applied to the different crops in his rotation. A careful study along this line, too, will show whether it is fertilization that is required to meet seeming deficiencies, for it frequently happens that the needs of the soil are not so much for added plant food as for better management of the soil in other respects.

Pages 197–198: The results of experiment which have been conducted with great care in a number of States show that where "extensive" methods are practiced certain elements need not be added in the fertilizers; that is, that the soil contains such an abundance of them that the plant is able to obtain a full supply, at least, for a long time. For example, it has been shown that on the chief sugar-producing soils of Louisiana and Mississippi, and on the cotton soils of Georgia and Texas, the addition of potash has been of less importance in the past than the other elements, and it frequently does not need to be included in the fertilizer, while phosphoric acid is always needed.

The results of field experiments on this plan in New Jersey, on reasonably good, loamy soils, indicate that phosphoric acid and potash are of much more importance in fertilizers for corn than nitrogen; whereas upon sandy soils nitrogen and potash are of relatively more importance than phosphoric acid; that is, even where "extensive" practice is used there are conditions where one or more of the elements are not required in order to secure maximum crops, which eliminates the necessity of an immediate outlay for those constituents that are not lacking. Where experiments of this sort have been carried out and the specific needs determined, it becomes necessary to assume that all of the constituents are required, and to apply the amounts and proportions of those which the general considerations of the soil, season, climate, and crop would seem to demand.

As already pointed out, the methods of fertilization here suggested, though in many instances apparently positive, are not to be interpreted as absolute rules, but rather to be used as guides, based upon the best information that it has been possible to obtain, both as a result of scientific inquiry and of practical experience.

Pages 211–212: The main point in this whole matter of fertilization is to understand that a fertilizer is a fertilizer because of the kind and form of plant food contained in it; and that its best action, other things being equal, is accomplished when the soil possesses good physical qualities, when the management is also good, and when systematic methods are planned and adopted. "Hit or miss" fertilization, even for these crops, may pay, and doubtless on the average does pay, as well as some other things that farmers do, but does not pay as well as it might if better methods were used.

APPENDIX B.

A SUMMARY OF THE GUARANTEED ANALYSES OF FERTILIZERS SOLD IN SEVERAL STATES.

In this review or analysis of the figures showing the composition of the brands of fertilizers sold in the several States, the guaranteed minimum compositions only are used, as these are usually expressed in whole numbers or even percentages, and as they in most cases agree very well with the amounts found by analyses. The figures for nitrogen occurring in some of the reports have been calculated to ammonia (NH_3) for purposes of comparison, and in a few cases small fractions of a percentage have been neglected and the result stated in the nearest whole number. None of the remarks or observations made in connection with the figures have been quoted from the official publications.

CONNECTICUT.[a]

During 1907 thirty-six individuals or firms have entered for sale in this State 279 brands of fertilizers, viz:

Special manures for particular crops	126
Other nitrogenous superphosphates	98
Bone manures and "bone and potash"	23
Fish, tankage, castor pomace, and chemicals	32
Total	279

Classification of the fertilizers analyzed.

1. Containing nitrogen as the chief active ingredient:
   - Nitrate of soda.
   - Sulphate of ammonia.
   - Dried blood.

[a] Biennial Report, Conn. Agr. Expt. Sta., 1907–8.

1. Containing nitrogen as the chief active ingredient—Continued.
    - Cotton-seed meal.
    - Castor pomace.
    - Linseed meal.
2. Containing phosphoric acid as the chief active ingredient:
    - Dissolved phosphate rock.
    - Basic slag.
    - Precipitated bone.
3. Containing potash as the chief active ingredient:
    - Carbonate of potash.
    - High-grade sulphate of potash.
    - Double sulphate of potash and magnesia.
    - Muriate of potash.
    - Kainit.
4. Containing nitrogen and phosphoric acid:
    - Bone manures.
    - Slaughterhouse tankage.
    - Dry ground fish.
5. Mixed fertilizers:
    - Nitrogenous superphosphates.
    - Special manures.
    - Home mixtures.
6. Miscellaneous fertilizers and manures:
    - "Vegetable potash."
    - Cotton hull ashes.
    - Wood ashes.
    - Lime and limekiln ashes.
    - Others, miscellaneous.

Commercial valuations allowed by the station.

	Cents per pound.
Nitrogen in nitrates	18½
ammonia salts	17½
Organic nitrogen in dry and fine ground fish, meat, and blood, and in mixed fertilizers	20½
fine bone and tankage	20½
coarse bone and tankage	15
Phosphoric acid, water soluble	5
citrate soluble	4½
of fine ground bone and tankage	4
of coarse bone and tankage	3
of cotton-seed meal, castor pomace, and ashes	4
of mixed fertilizers, if insoluble in ammonium citrate	2
Potash as high-grade sulphate in forms free from muriate (or chlorids)	5
as muriate	4¼

Composition of nitrogenous superphosphates summarized.

Phosphoric acid.		Ammonia.		Potash.	
Number of brands.	P_2O_5.	Number of brands.	NH_3.	Number of brands.	K_2O.
	Per cent.		*Per cent.*		*Per cent.*
2	10	2	8	9	10
17	9	2	7	1	8.8
34	8	1	6	4	8
14	7	9	5	13	7
20	6	2	4.5	13	6
6	5	17	4	4	5
7	4	2	3.5	2	4.5
		34	3	16	4
		8	2.5	1	3.8
		6	2	2	3.5
		2	1.5	6	3
		15	1	1	2.5
				24	2
				2	1.5
				2	1

Composition of nitrogeneous superphosphates.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	10	3	2.5	1	7	5	6
1	10	2.5	3.5	1	7	5	5
1	9	4	6	1	7.5	4.5	10
2	9	3.5	4.5	1	7.5	4.5	8.8
2	9	3	8	2	7	4	7
1	9	3	4	1	7	1	2
7	9	3	2	1	7	1	1
1	9	2.5	2	1	6.5	8	2
1	9	1.5	2	2	6	7	5
2	9	1	2	1	6	6	6
1	8	5	7	2	6	4	10
5	8	4	7	1	6	4	7
1	8	4	6	3	6	4	6
4	8	3	6	3	6	3	10
6	8	3	4	1	6	3	8
2	8	2.5	3	1	6	3	7
1	8	2.5	1.5	2	6	3	2
1	8	2	3	2	6	2.5	2
3	8	2	2	1	6	1.5	3
1	8	1	5	1	5	4	4
3	8	1	4	2	5	3	3
1	8	1	3.5	1	5	3	10
3	8	1	2	1	5	2	4
1	8	1	1.5	1	5	1	2
1	8	1	1	1	4	5	6
1	7	8	10	1	4	4	3.8
1	7	5	10	3	4	3	4
1	7	5	8	1	4	2.5	6
3	7	5	7	1	4	2	4

Composition of special brands for tobacco.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	9	3	2	1	6	5	1
1	8	4	5	2	6	4	6
2	8	4	4	1	6	3	10
1	8	3	3	1	5	7	10
1	8	2.5	6	2	5	5.5	5
2	8	2.5	3	1	5	3.5	7
1	8	2	4	1	4	7	10
1	7	6	10	1	4	6	6
2	7	5	6	2	4	5	5
1	7	4	8	1	4	4.5	3
2	6	7.25	9	4	3	5.5	5
2	6	6	11	1	3	5	5

Composition of special brands for potatoes.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	9	2	5	1	7	4	7
1	9	2	2	1	7	4	6
1	8	4.5	6	1	7	2	6
4	8	4	7	2	7	2	4
1	8	3.25	7	1	7	1.5	2
2	8	3	7	1	7	1	3
3	8	3	6	3	6	4	10
1	8	3	5	2	6	4	6
1	8	3	4	4	6	3	5
3	8	2.5	6	1	6	2.5	4
4	8	2.5	3	1	6	2	4
4	8	2	10	1	5	2	10
1	8	2	4	1	5	2	6
1	8	2	3	1	4	4	8
1	7	6	5	1	4	1	8
1	7	4.5	8				

Composition of special brands for corn, grain, and grass.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	10	4	7	1	7	2	2
2	9	3	2	1	7	1.5	2
1	9	2	5	1	6	5	5
1	8	6	8	1	6	4.75	2
1	8	3	6	1	6	4.25	7
1	8	3	4	1	6	4	6
4	8	2.5	1	1	6	2.5	12
1	8	2	5	1	6	2	3
1	8	2	3	1	5	6	2
3	8	2	2	1	4	6	6
2	7	7.5	7	1	4	6	2
1	7	5	7	1	4	3.5	5
1	7	5	6	1	3.9	10.25	8

MASSACHUSETTS.

The following explanatory statement is taken from the official bulletin, giving the results of the fertilizer inspection for the season of 1907:[a]

The organic nitrogen in the mixed goods is valued as coming from the best grade of raw materials and is counted at 20½ cents per pound. This method of valuing the organic nitrogen in mixed fertilizers will, of course, give a too high value on those goods in which the organic nitrogen has been derived from low-grade materials which possess slowly available nitrogen. This seems to be the only course, however, at present, as the ordinary methods of analysis will not discriminate between the available and inert forms of organic nitrogen.

Soluble phosphoric acid is valued at 5 cents per pound, citrate soluble or reverted acid at 4½ cents, and the phosphoric acid which is insoluble in ammonium citrate (usually termed insoluble phosphoric acid) at 2 cents per pound. Potash is valued according to the form in which it is found present in the fertilizer. Whenever a potash test is reported in the tables without comment or footnote, it will be understood that sufficient chlorine was present to unite with all of the potash. Every brand of complete fertilizer is tested for chlorides, and if sufficient chlorine is found to unite with all of the potash, it is taken for granted that the potash exists in the form of muriate and is counted as worth 4½ cents per pound. The presence of chlorine does not necessarily prove that it is in combination with the potash, but its presence in a fertilizer supposed and advertised to be free from chlorides or where the potash is said to be present as sulphate or carbonate is just as objectionable as though it was actually in combination with the potash. Whenever the potash is guaranteed to be present as sulphate and the analysis shows the presence of chlorine, a footnote has been used to indicate how much is present in each form. Wherever only very small quantities of chlorides are present the potash has been reported as sulphate. Potash in form of sulphate has been valued at 5 cents per pound.

Whenever the potash is guaranteed as carbonate a test has been made for chlorides and sulphates, and a footnote indicates how much potash is present in each form. Potash in form of carbonate has been valued at 8 cents per pound.

Whenever it was known that potash had been derived wholly or in part from organic sources, in mixed fertilizers, a total potash test has been made and will be found reported in a footnote. No attempt has been made to place a valuation on that portion of the potash which is insoluble in water. It no doubt has a commercial value, but as we have no basis for establishing its worth, the results have simply been reported without comment. It should not be understood that all of the potash in vegetable organic compounds is insoluble in water. As a matter of fact about 80 per cent of the potash in cotton-seed meal is recovered in a water-soluble potash test. * * *

The agricultural value of a fertilizer represents its crop-producing power, which is far from constant on all soils.

The beneficial effect of any fertilizer on a particular soil depends on whether the fertilizer in question contains those elements of plant food in suitable

[a] Inspection of Commercial Fertilizers, Mass. Agr. Expt. Sta., Bul. No. 119, December, 1907.

quantity and quality in which the soil is deficient. In other words, the supply of plant food in soils varies widely, and every user of commercial fertilizers must select his fertilizer according to the conditions of his soil and the requirements of the crop which he wishes to raise. We are often asked which is the best mixed fertilizer to use. The consumer can better answer this question for himself by a study of his soil conditions and crop requirements. A general statement may be made, however, to the effect that, all conditions being equal, the consumer should select those fertilizers which give the greatest amount of plant food in suitable and available forms for the least money. A study of the tables of analyses should furnish reliable data in making fertilizer selections. The tables show the quality and quantity of the various essential elements of plant food with the possible exception of organic nitrogen. Prescribed methods of analysis do not include a wholly reliable means of determining the availability of organic nitrogen, and in all valuations, in case of the mixed goods, it is assumed that the organic nitrogen is present in the best forms.

The high-grade fertilizers will, as a general rule, be the most economical ones to buy, and the low-grade fertilizers will, ordinarily, be the most expensive ones. In the manufacture of the best goods only high-grade raw materials and chemicals can be used, as the formula has to be made up of compounds whose united composition will furnish the desired quantity and quality of plant food and whose combined weight must not exceed 2,000 pounds. On the other hand, in the manufacture of very low-grade fertilizers the necessary compounds to supply the percentage of nitrogen, phosphoric acid, and potash which is guaranteed might be supplied in 1,200 to 1,500 pounds of material of good quality, and the remainder, to make up the ton weight, will be a filler of some sort which oftentimes has no fertilizing value whatever. Besides this, the consumer is obliged to pay freight and cartage on low-valued and worthless material. Many low-grade goods contain a high percentage of phosphoric acid. It should be borne in mind that phosphoric acid is the cheapest of the essential elements of plant food and that some of the low-grade mixed goods contain an excess of this material. Cheap or low-grade fertilizers are sometimes made up of crude stock having a comparatively low commercial and agricultural value.

There were 317 brands of fertilizers entered for sale in the State. Of these, there were 249 brands of complete fertilizers, with manufacturers' guarantees of the percentage of phosphoric acid, ammonia (nitrogen), and potash, 155 of them being special brands for special crops. An analysis of these figures for the nitrogenous superphosphates is given herewith.

Composition of nitrogenous superphosphates summarized.

Phosphoric acid.		Ammonia.		Potash.	
Number of brands.	P_2O_5.	Number of brands.	NH_3.	Number of brands.	K_2O.
	Per cent.		*Per cent.*		*Per cent.*
1	11	1	18	2	12
3	10	1	10.25	1	11
22	9	1	8	30	10
2	8.5	1	7.75	1	9.5
105	8	1	7	1	8.75
40	7	1	6.5	1	8.5
2	6.5	9	6	9	8
40	6	2	5.75	2	7.5
15	5	6	5.5	29	7
1	4.5	16	5	2	6.5
13	4	3	4.75	26	6
1	3.5	7	4.5	2	5.5
2	3	7	4.25	22	5
1	2.9	45	4	2	4.75
1	.75	9	3.5	3	4.5
		2	3.25	24	4
		43	3	1	3.75
		30	2.5	1	3.5
		1	2.25	24	3
		32	2	5	2.5
		1	1.75	2	2.25
		9	1.5	46	2
		7	1.25	8	1.5
		14	1	4	1
				1	.25

Composition of nitrogeneous superphosphates.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	11	3	10	3	8	2.5	6
2	10	4	7	1	8	2.5	5
1	10	3	2.5	11	8	2.5	3
1	9	4.25	2	7	8	2.5	1.5
2	9	3.5	4.75	2	8	2	10
1	9	3.5	4.5	1	8	2	5
1	9	3	2.5	1	8	2	4
9	9	3	2	5	8	2	3
1	9	2.5	2.25	5	8	2	2
1	9	2.5	5	1	8	1.75	2
1	9	2.5	3	2	8	1.5	10
1	9	2.25	2.25	3	8	1.5	2
2	9	2	2	1	8	1.25	10
1	9	2	4	1	8	1.25	3.5
1	9	1.5	2	4	8	1.25	2
1	8.5	1.5	2.5	1	8	1	5
1	8.5	1	1.5	3	8	1	4
1	8	6.5	4	1	8	1	3
1	8	6	8	2	8	1	2
1	8	5.5	8	1	7	8	7.5
1	8	5.5	5	1	7	7	8
1	8	5	10	1	7	6	10
1	8	5	7	1	7	6	5
1	8	4.5	6	1	7	5.5	12
2	8	4.25	7	4	7	5	7
1	8	4.25	5	3	7	5	6
13	8	4	7	2	7	5	5
1	8	4	6	1	7	4.5	10
2	8	4	5	1	7	4.5	8.5
2	8	4	4	2	7	4.25	10
1	8	4	3	1	7	4.25	8.75
1	8	3.5	6.5	2	7	4	10
1	8	3.5	6	1	7	4	9.5
1	8	3.5	4	1	7	4	7
1	8	3.5	10	2	7	4	6
1	8	3.5	8	1	7	3	8
1	8	3.25	7	1	7	3	5
5	8	3	6	1	7	3	4
7	8	3	4	2	7	2	6
2	8	3	5	2	7	2	4
1	8	3	3	2	7	2	2
2	7	1.5	2	1	5	6	2.5
1	7	1.25	2	1	5	5.75	7
3	7	1	1	1	5	5.75	2.5
1	6.5	4.75	4.5	1	5	5	5
1	6.5	2.5	12	1	5	4.75	2
1	6	6	11	1	5	4	7
1	6	6	6	1	5	3.5	5
1	6	5	6	1	5	3	3
1	6	5	5	1	5	3	2
1	6	5	4	1	5	2	10
1	6	5	1	2	5	2	2
1	6	4.5	7.5	1	5	1	10
2	6	4.5	7	1	4.5	2	2
7	6	4	10	1	4	10.25	8
5	6	4	6	1	4	7	10
1	6	3.25	10	1	4	6	6
5	6	3	10	1	4	6	2
1	6	3	8	1	4	4.75	5
2	6	3	5	1	4	4	8
1	6	3	4	1	4	4	7
1	6	2.5	4.5	1	4	4	5
2	6	2.5	2	1	4	4	3.75
1	6	2	4	2	4	3	4
1	6	2	3	1	4	2.5	2
3	6	2	2	1	4	1	8
1	6	1	2	1	3.5	4	3
1	5	18	3	2	3	5.5	5.5
1	5	6	5	1	2.9	7.75	6.5
....	....	....	....	1	.75	5.5	.25

Composition of special brands for tobacco.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	9	2	4	1	7	6	10
1	9	3	2.5	1	7	5.5	12
1	8	2	4	1	7	5	6
2	8	2.5	3	1	7	4.25	8.75
1	8	2.5	6	1	6	6	11
1	8	5	10	1	6	5	1
1	8	4	7.4	1	5	4	7
1	8	4	5 4	1	4	7	10
1	8	4	5	1	4	5	5
1	8	3	3	2	3	5.5	5.5

Composition of special brands for potatoes.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	9	3.5	4.75	1	7	6	5
1	9	2.5	5	1	7	4.5	8.5
1	9	2	2	1	7	4	7
1	8.5	1.5	2.5	2	7	3	6
1	8	4.5	6	1	7	7	8
4	8	4	7	1	7	3	4
1	8	3.5	10	2	7	2	6
1	8	3.5	6.5	2	7	2	4
1	8	3	6	3	6	4	10
1	8	3	5	1	6	4	6
1	8	2.75	5	1	6	3	10
2	8	2.5	6	2	6	3	5
1	8	2.5	5	1	6	2.5	4.5
8	8	2.5	3	1	6	2	4
2	8	2	10	1	4	4	8
1	8	2	3	1	4	1	8
1	8	1.5	10				

Composition of special brands for market-garden crops.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	9	4.25	2	1	7	4 25	10
1	8	5.5	8	1	6.5	5	4.5
8	8	4	7	1	6	6	6
1	8	5	6	1	6	5	6
1	8	4	4	2	6	4.5	7
1	8	3.5	6	2	6	3	10
1	8	3.25	7	1	5	6	5
1	8	3	6	1	5	3.5	5
1	8	2	5	1	5	2	10
2	8	2	2	1	4	4	7
1	8	1	10	1	4	4	5
1	7	5	6	1	4	2.5	2
1	7	5	5	1	2.9	8	6.5

Composition of special brands for corn, grain, and grass.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
2	10	4	7	1	7	4	10
2	9	3	2	1	7	2	2
1	9	2.5	3	2	7	1.5	2
1	8	6	8	1	7	1	1
1	8	5.5	5	1	6.6	2.5	12
1	8	4	3	1	6	5	5
1	8	3.25	8	1	6	4.5	7
1	8	3	6	1	6	3	10
3	8	3	4	1	6	3	8
4	8	2.5	1.5	1	6	2	3
4	8	2	3	1	5	5.5	7
1	8	2	2	2	5	6	2.5
1	8	1.5	2	1	5	5	5
1	7	8	7.5	1	5	5	2
1	7	7	8	1	4	6	2
1	7	5	7	1	4	6	6
1	7	5	6	1	3.9	10.25	8

MAINE.[a]

The following explanatory statement is taken from pages 85–89 of the official bulletin, giving the results of the fertilizer inspection by the Maine station for 1908:

The law regulating the sale of commercial fertilizers in this State calls for two bulletins each year. The first of these contains the analyses of the samples received from the manufacturer, guaranteed to represent, within reasonable limits, the goods to be placed upon the market later. The second bulletin contains the analyses of the samples collected in the open market by a representative of the station.

In the tables which follow the discussion there are given the results of the analyses of the manufacturers' samples of licensed brands. The tables include all the brands which have been licensed to February 10, 1908. Dealers are cautioned against handling brands not given in this list without first writing the station. * * *

To produce profitable crops and at the same time to maintain and even to increase the productive capacity of the soil may rightly be termed "good farming." Many farmers are able to do this, and the knowledge of how to do it has been largely acquired through years of experience, during which the character of the soil, its adaptibility for crops, and the methods of its management and manuring have been made the subjects of careful study, without, however, any definite and accurate knowledge concerning manures and their functions in relation to soils and crops. * * *

Soils vary greatly in their capabilities of supplying food to crops. Different ingredients are deficient in different soils. The way to learn what materials are proper in a given case is by observation and experiment. The rational method for determining what ingredients of plant food a soil fails to furnish in abundance, and how these lacking materials can be most economically supplied, is to put the question to the soil with different fertilizing materials and get the reply in the crops produced. * * *

It is good farming to make the most of the natural resources of the soil and of the manures produced on the farm, and to depend upon artificial fertilizers only to furnish what more is needed. It is not good economy to pay high prices for material which the soil may itself yield, but it is good economy to supply the lacking ones in the cheapest way. The rule in the purchase of costly commercial fertilizers should be to select those that supply, in the best forms and at the lowest cost, the plant food which the crop needs and the soil fails to furnish.

Plants differ widely with respect to their capacities for gathering their food from soil and air; hence the proper fertilizer in a given case depends upon the crop as well as upon the soil. The fertility of the soil would remain practically unchanged if all the ingredients removed in the various farm products were restored to the land. * * *

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[a] Maine Agr. Expt. Sta., Bulletin 153, March, 1908.

The term "form" as applied to a fertilizing constituent has reference to its combination or association with other constituents which may be useful, though not necessarily so. The form of the constitutent, too, has an important bearing upon its availability, and hence upon its usefulness as plant food. Many materials containing the essential elements are practically worthless as sources of plant food because the form is not right; the plants are unable to extract them from their combinations; they are "unavailable." In mauy of these materials the form may be changed by proper treatment, in which case they become valuable not because the element itself is changed, but because it then exists in such form as readily to feed the plant. * * *

The agricultural value of any fertilizing constituent is measured by the value of the increase of the crop produced by its use, and is, of course, a variable factor, depending upon the availability of the constituent, and the value of the crop produced. The form of the materials used must be carefully considered in the use of manures. Slow-acting materials can not be expected to give profitable returns upon quick-growing crops, nor expensive materials profitable returns when used for crops of relatively low value.

The agricultural value is distinct from what is termed "commercial value," or cost in market. This last is determined by market and trade conditions, as cost of production of the crude materials, methods of manipulation required, etc. Since there is no strict relation between agricultural and commercial or market value, it may happen that an element in its most available form and under ordinary conditions of high agricultural value, costs less in market than the same element in less available forms and of a lower agricultural value. The commercial value has reference to the material as an article of commerce, hence commercial ratings of various fertilizers have reference to their relative cost and are used largely as a means by which the different materials may be compared.

There were 209 brands of fertilizers placed upon the market, of which 186 brands were complete fertilizers containing phosphoric acid, ammonia (nitrogen), and potash, which we will call nitrogenous superphosphates. Of these, 68 brands were designated as special brands for potatoes, and 35 brands for corn, grass, and grain. An analysis of the guaranteed figures shows the following composition of the brands of fertilizers sold in the State of Maine:

Composition of nitrogeneous superphosphates summarized.

Phosphoric acid.		Ammonia.		Potash.	
Number of brands.	P_2O_5.	Number of brands.	NH_3.	Number of brands.	K_2O.
	Per cent.		*Per cent.*		*Per cent.*
1	10	1	7	1	12
10	9	1	6	43	10
99	8	9	5	6	8
30	7	1	4.75	23	7
38	6	6	4.50	12	6
4	5	22	4	8	5
3	4	2	3.5	15	4
1	3	51	3	23	3
....	....	29	2.5	2	2.5
....	....	24	2	32	2
....	....	6	1.5	13	1.5
....	....	11	1.25	8	1
....	....	22	1	....	....
....	....	1	.5	....	....

Composition of nitrogeneous superphosphates.

Number of brands.	Phosphoric acid.	Ammonia	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	10	4	7	3	7	5	7
1	9	4	6	6	7	4.5	10
5	9	3	2	3	7	3	8
2	9	2	2	1	7	3	5
1	9	2	12	2	7	2	4
1	9	1.5	2	1	7	2	3
2	8	5	7	2	7	1.5	2
1	8	4	10	8	7	1	1
1	8	4	6	1	7.5	1	3
1	8	3.5	4	1	6	5	5
17	8	3	7	17	6	4	10
4	8	3	6	1	6	3.5	10
6	8	3	4	10	6	3	10
4	8	2.5	6	4	6	3	5
14	8	2.5	3	1	6	2	2
11	8	2.5	1.5	1	6	1.5	3
3	8	2	10	1	6	1	6
2	8	2	5	1	6	1	4
1	8	2	4	1	6	1	2
5	8	2	3	1	5	4.75	2
6	8	2	2	1	5	4	10
11	8	1.25	2	1	5	3	10
4	8	1	4	1	5	1	10
1	8	1	3	1	4	6	6
2	8	1	2	1	4	1	8
2	8.5	1.5	2.5	1	4	1	2
2	7	5	10	1	3	7	8
1	7	5	8				

Composition of special brands for potatoes.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	9	2	12	1	7.5	1	3
1	8.5	1.5	2.5	1	7	5	10
1	8	4	10	3	7	4.5	10
6	8	4	7	1	7	3	8
4	8	3	6	1	7	3	5
1	8	3	4	1	7	2.5	.8
3	8	2.5	6	2	7	2	4
1	8	2.5	5	12	6	4	10
11	8	2.5	3	5	6	3	10
2	8	2	10	3	6	3	5
1	8	2	4	1	6	1.25	4
1	8	2	3	1	6	1	6
1	8	2	2	1	4	1	8
1	8	1	4				

Composition of special brands for corn, grain, and grass.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	10	4	7	2	8	1.25	2
1	9	3	2	1	7	5	7
1	8.5	1.5	2.5	1	7	1.5	2
1	8.5	1	1.5	3	7	1	1
1	8	5	7	3	6	3	10
3	8	4	7	1	6	3	5
1	8	2.5	6	1	6	1.5	3
5	8	2.5	1.5	1	5	5	2
3	8	2	3	1	4	6	6
4	8	2	2				

NORTH CAROLINA.

There were 1,805 brands of fertilizers registered for sale in North Carolina in the spring season of 1908. The following explanatory matter or advice as to making suitable selections from this great mass of material is taken from the official bulletin giving the results of the inspection,[a] and is probably about all that can be safely and positively stated in a general way with our present knowledge of fertilizers, soil, and crops, but it is in strange contrast with the assurauce and knowledge implied in the names and compositions of the brands put out by the different mauufacturers:

The analyses presented in this bulletin are of samples collected by the fertilizer inspectors of the department, under the direction of the commissioner of agriculture, during the spriug months of 1908. They should receive the careful study of every farmer in the State who uses fertilizers, as by comparing the analyses in the bulletin with the claims made for the fertilizers actually used the farmer can kuow by or before the time fertilizers are put in the ground whether or not they contain the fertilizing constituents in the amount they were claimed to be present. * * *

Water-soluble ammonia.—The main materials furnishing ammonia in fertilizers are nitrate of soda, sulphate of ammouia, cotton-seed meal, dried blood, tankage, and fish scrap. The first two of these (nitrate of soda and sulphate of ammouia) are easily soluble in water and become well distributed in the soil where plant roots cau get at them. They are, especially the nitrate of soda, ready to be taken up by plants, and are therefore quick-acting forms of ammonia. It is mainly the ammonia from nitrate of soda and sulphate of ammonia that will be designated under the heading of water-soluble ammonia.

Organic ammonia.—The ammonia in cotton-seed meal, dried blood, tankage, fish scrap, and so on is included under this heading. These materials are insoluble in water, and before they can feed plants they must decay and have their ammonia changed, by the aid of the bacteria of the soil, to nitrates, similar to nitrate of soda.

They are valuable then as plant food in proportion to their content of ammonia and the rapidity with which they decay in the soil, or rather the rate of decay, will determine the quickness of their action as fertilizers. With short season, quick-growing crops, quickness of action is an important consideration, but with crops occupying the land during the greater portion or all of the growing season it is better to have a fertilizer that will become available more slowly, so as to feed the plant till maturity. Cotton-seed meal and dried blood decompose fairly rapidly, but will last the greater portion, if not all, of the growing season in this State. While cotton seed and tankage will last longer than meal aud blood, none of these act so quickly or give out so soon as nitrate of soda and sulphate of ammonia.

Total ammonia is made up of the water-soluble and organic; it is the sum of these two.

The farmer should suit, as far as possible, the kind of ammonia to his different crops, and a study of the forms of ammonia, as given in the tables of analyses, will help him to do this.

The general character of the brands is as follows:

		Brands.
Material valued only for phosphate supplied:		
Acid phosphate, slag, and raw rock		236
Material valued only for nitrogen supplied:		
Nitrate of soda	45	
Sulphate of ammonia	11	
Fish scrap	6	
Dried blood	8	
	—	70
Material valued only for potash supplied:		
Kainit	61	
Muriate of potash	37	
Sulphate of potash	24	
Mixed salts	1	
	—	123

[a] Analyses of Fertilizers—Spring Season, 1908. The Bulletin of the N. C. Dept. of Agr., vol. 29, No. 4, Apr., 1908.

	Brands.
Material valued only for phosphoric acid and nitrogen supplied:	
Bone and tankage	33
Mixed fertilizers:	
Containing nitrogen and potash	5
Containing phosphoric acid and potash	246
Complete fertilizers, containing phosphoric acid, nitrogen, and potash	1,092
	1,805

Of the 1,092 brands of complete fertilizers, 504 are special brands for special crops, as follows: Three brands for fruit; 176 brands for tobacco; 11 brands for peanuts; 38 brands for corn, grain, and grass; 94 brands for cotton; 68 brands for potatoes; 114 brands for truck.

Nearly half of the complete fertilizers, or nearly a third of the whole number of brands offered for sale, purport to be special brands for special crops.

The 246 fertilizers containing only phosphoric acid and potash have the following composition:

Number of brands.	Phosphoric acid.	Potash.
	Per cent.	*Per cent.*
1	21	37
1	13	4
2	13	3
3	12	6
7	12	5
7	12	4
8	12	3
2	12	1
4	11	5
6	11	2
5	11	1
4	10	6
12	10	5
42	10	4
13	10	3
81	10	2
1	9	4
5	8	5
38	8	4
1	8	2
3	7	5

The following special brands for special crops are contained in the phosphoric-acid and potash fertilizers:

Peanuts.

Number of brands.	Phosphoric acid.	Potash.
	Per cent.	*Per cent.*
1	11	2
1	10	2
3	8	4
3	7	5

Potatoes.

Number of brands.	Phosphoric acid.	Potash.
	Per cent.	*Per cent.*
1	10	6
1	10	2

Corn, grain, and grass.

Number of brands.	Phosphoric acid.	Potash.
	Per cent.	*Per cent.*
1	12	5
3	12	4
1	10	6
5	10	4
5	10	3
11	10	2
12	8	4

Composition of brands of complete fertilizers summarized.

Phosphoric acid.		Ammonia.		Potash.	
Number of brands.	P_2O_5.	Number of brands.	NH_3.	Number of brands.	K_2O.
	Per cent.		*Per cent.*		*Per cent.*
1	25	1	27.5	17	10
1	23	1	11	2	9
1	17	20	10	17	8
1	17	3	7.5	59	7
2	15	44	7	37	6
2	12	1	6.75	98	5
1	11	15	6	1	4.5
48	10	2	5.5	117	4
26	8.5	76	5	282	3
662	8	2	4.75	2	2.75
81	7	7	4.5	42	2.5
79	6	1	4.25	2	2.25
26	5	91	4	364	2
9	4	11	3.5	7	1.5
3	3	2	3.25	44	1
3	2	246	3		
1	1	42	2.75		
		132	2.5		
		22	2.25		
		329	2		
		41	1		

Composition of brands of complete fertilizers.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	25	4	6	5	9	2	3
1	23	2	2	18	9	2	2
1	17	3.5	3	17	9	2	1
1	16	2	2.5	4	9	1	3
1	15	4.25	3	8	9	1	2
1	15	3	5	1	8.5	3	4
2	12	2	2	1	8.5	3	2.5
1	11	3	4	1	8.5	2.75	2
3	10	4	5	4	8.5	2.5	2.5
2	10	4	4	3	8.5	2.5	1
2	10	3	10	15	8.5	2	2
6	10	3	3	1	8.5	2	1.5
1	10	3	2	1	8	6	6
1	10	2	5	1	8	6	5
1	10	2	4	5	8	5	7
1	10	2	3	7	8	5	5
15	10	2	2	1	8	5	3
1	10	1	5	1	8	5	2
5	10	1	3	1	8	4.75	4
9	10	1	1	1	8	4.75	2.75
1	9	27.5	2	4	8	4.5	7
1	9	6.75	2	1	8	4.5	4
1	9	5	7	2	8	4	7
1	9	5	3	4	8	4	6
1	9	4	7	3	8	4	5
1	9	4	5	40	8	4	4
1	9	4	2.5	6	8	4	3
1	9	3.5	9	1	8	4	2.5
3	9	3.5	5	1	8	4	2
2	9	3	6	1	8	3.5	7.5
1	9	3	5	2	8	3.5	5
1	9	3	4	1	8	3.5	4
13	9	3	3	1	8	3.5	3
4	9	3	2	1	8	3.25	2
1	9	2.25	1	6	8	3	10
22	9	2.75	2	1	8	3	6
5	9	2.5	5	7	8	3	5
4	9	2.5	3	15	8	3	4
6	9	2.5	2	146	8	3	3
4	9	2.5	1	8	8	3	2.5
9	9	2.25	4	11	8	3	2
1	9	2.25	3	1	8	2.75	10
8	9	2.25	1	2	1	2.75	4
1	9	2	4	1	8	2.75	3
9	8	2.75	2.5	1	6	10	2.5
6	8	2.75	2	2	6	10	2
2	8	2.5	6	1	6	7	7
1	8	2.5	5	3	6	7	6
3	8	2.5	4	20	6	7	5
55	8	2.5	3	1	6	6	8
5	8	2.5	2.5	2	6	6	7
33	8	2.5	2	5	6	6	6
5	8	2.5	1.5	1	6	5.5	10
1	8	2.5	1	15	6	5	7
1	8	2.25	2.5	2	6	5	6
2	8	2.25	2.25	3	5	5	5
3	8	2	10	1	6	4.5	4
3	8	2	6	1	6	4	8
5	8	2	5	6	6	4	4
8	8	2	4	1	6	3	6
11	8	2	3	5	6	3	3
210	8	2	2	1	6	3	2.5
1	8	2	1	1	6	2.5	3
9	8	1	4	2	6	2	6
5	8	1	3	1	6	2	5
1	7	8	5	1	6	2	4.5
1	7	7.5	10	5	5	10	3
16	7	7	7	7	5	10	2.5
1	7	7	5	2	5	10	2
1	7	7	4	1	5	8	3
1	7	6	6	2	5	7	5
2	7	6	5	1	5	6	9
10	7	5	8	1	5	6	7
8	7	5	7	2	5	5	5
1	7	5	6	1	5	4	6
18	7	5	5	1	5	3	6
1	7	5	4	1	5	2	10
1	7	4.5	6	1	5	2	6
1	7	4	8	1	5	2	5

Composition of brands of complete fertilizers—Continued.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	7	4	7	1	4	7.5	2.5
1	7	4	5	1	4	4	8
5	7	4	4	3	4	4	6
1	7	3.5	7	2	4	4	4
1	7	3.25	2.75	1	4	3	6
1	7	3	10	1	4	3	5
1	7	3	7	2	3	10	4
1	7	3	5	1	3	8.5	2
1	7	3	4	1	2	11	4
2	7	3	3	1	2	10	5
1	7	3	2	1	2	7.5	1.5
1	7	2	5	1	1	8	10
1	7	2	4				

There are 184 combinations in these 1,092 brands, not counting the differences in material of which they are composed. There are 37 combinations embracing 833 brands, or 76 per cent of the whole number, which have 6 or more brands with identical combinations, as follows:

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
210	8	2	2	9	10	1	1
146	8	3	3	9	9	2.25	4
55	8	2.5	3	9	8	2.75	2.5
40	8	4	4	9	8	1	4
33	8	2.5	2	8	9	2.25	1
22	9	2.75	2	8	9	1	2
20	6	7	5	8	8	3	2.5
18	9	2	2	8	8	2	4
18	7	5	5	8	7	5	7
17	9	2	1	7	8	5	5
16	7	7	7	7	8	3	5
15	10	2	2	7	5	10	2.5
15	8	2	2	6	10	3	3
15	8	3	4	6	9	2.5	2
15	6	5	7	6	8	4	3
13	9	3	3	6	8	3	10
11	8	2	3	6	8	2.75	2
11	8	3	2	6	6	4	
10	7	5	8				

Composition of special brands for tobacco.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
2	9	3.5	5	5	8	3	5
7	9	3	6	6	8	3	4
2	9	2.75	2	49	8	3	3
1	9	2.5	3	2	8	2	3.5
4	9	2.5	2	3	8	3	2
1	9	2.75	4	1	8	2.75	4
4	9	2	2	1	8	2.75	2.5
1	8.5	3	4	13	8	2.5	2.5
1	8.5	3	2.5	21	8	2.5	3
1	8.5	2.75	2	2	8	2.25	2.5
1	8.5	2.5	2.5	2	8	2	4
1	8.5	2	2	2	8	2	3
1	8	4.75	4	20	8	2	2
1	8	4	7	1	6	3	3
1	8	4	5	1	5	6	9
1	8	4	3	1	5	4	6
1	8	4	2.5	2	4	4	6
9	8	4	4	1	4	3	6
1	8	3.5	5	1	4	3	5
1	8	3	10				

Composition of special brands for cotton.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
2	10	3	3	19	8	3	3
1	10	2	3	2	8	3	2
2	10	2	2	1	8	2.75	2
1	10	1	3	1	8	2.5	3
4	9	3	4	1	8	2.5	2
7	9	2.75	2	1	8	2.5	1.5
1	9	2.5	1	31	8	2	2
4	9	2	1	1	7	3.25	2.75
2	9	1	3	1	7	2	5
2	8.5	2	2	1	6	3	3
1	8	4	6	1	6	3	2.5
5	8	4	4	1	4	4	4
1	8	4	3				

Composition of special brands for potatoes.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	16	2	2.5	1	7	3.6	7
1	8	5	7	1	7	3	10
1	8	4.5	7	1	7	3	7
1	8	4	5	1	6	7	7
2	8	4	4	1	6	7	6
1	8	3	5	7	6	7	5
1	8	3	4	1	6	6	7
5	8	3	3	8	6	5	7
3	8	2	10	1	6	5	5
1	8	2	5	1	6	4	4
1	7	7.5	10	1	6	2	6
4	7	7	7	1	5	7	5
5	7	5	8	1	5	6	7
6	7	6	7	1	5	3	6
3	7	5	5	1	6	2	10
1	7	4	8	1	4	8	8
1	7	4	7				

Composition of special brands for corn, grain, and grass.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	11	3	4	3	9	1	2
1	10.5	2	5	1	8	3	6
1	10	2	4	12	8	2	2
1	10	2	2	1	8	1	3
1	10	1	5	2	6	3	3
4	10	1	3	2	5	10	2
3	10	1	1	1	5	2	5
1	9.6	2	1	1	4	7.5	2.5
1	9	2	1	1	1	8	10

Composition of special brands for truck crops.

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
1	25	4	6	1	7	8	5
3	10	4	5	9	7	7	7
1	10	4	4	2	7	6	5
2	10	3	10	5	7	5	8
1	10	2	2	2	7	5	7
1	9	3.5	9	12	7	5	5
1	8	6	6	1	7	5	4
1	8	6	5	1	7	4	5
3	8	5	7	1	7	3	5
5	8	5	5	2	6	10	2
1	8	5	3	1	6	7	6
1	8	4.5	7	11	6	7	5
1	8	4.5	4	2	6	6	6
1	8	4	5	3	6	5	7
7	8	4	4	1	6	5	6
1	8	4	3	1	6	5	5
3	8	3	10	2	6	2.75	8
1	8	3	3	1	6	2.75	4
1	8	3	4	1	6	2	4.5
1	8	2.5	6	5	5	10	3
3	8	2.5	4	4	5	10	2.5
1	8	2.5	3	1	5	8	3
2	8	2	4	1	5	5	5
1	8	2	2.25				

ALABAMA.

The following extracts from the Alabama law and comments on the same are takeu from the official bulletin giving the results of the fertilizer inspection for 1908:[a]

"SEC. 6. No complete fertilizer, acid phosphate with potash, acid phosphate with nitrogen, or plain acid phosphate shall be sold in this State which contains less than 14 per cent plaut food, namely, available phosphoric acid, nitrogen calculated as ammouia, and potash, either singly or in combination: *Provided*, That no complete fertilizer shall be sold in the State which contaius less than 1.65 per cent of nitrogen, equivalent to 2 per cent of ammonia.

"SEC. 10. No person, company, dealer, or agent shall sell, expose, or offer for sale in this State any pulverized leather, raw, steamed, roasted, or in any other form, either as a fertilizer or fertilizer material, without first having made full and explicit statement of the fact and registration with the commissioner of agriculture and industries, and furnishing satisfactory proof that the nitrogen is sufficiently available and valuable for the purpose for which it is sold."

As a result of the enactment of the legislation referred to, the quality of the fertilizers found upon the market during the preseut season is considerably higher than heretofore, though the increase in plant food is chiefly in the phosphoric acid of the fertilizer. It is noted that owing to the change in the minimum limit of plant food some brands supplying the essential fertilizing constituents in entirely different proportions from those heretofore supplied by the brands upon the market have been listed for sale during the present season, and it seems quite probable that good results will follow the elimination of such fertilizers as the 10 : 1 : 1 goods. Fertilizers of this last-mentioned grade supply only 1 per cent each of potash aud ammonia, and where the practice of applying one sack per acre of such a mixture has been adopted, only two pounds each of ammonia and potash are employed per acre of land. Inasmuch as many of our average soils to a depth of 6 inches will weigh about 2,000,000 pounds per acre, it will be seen that the application of such small amounts of ammonia and potash would add to the soil a relatively insignificant amount of plant food, and where these two particular constituents are needed by the soil they are usually needed in much larger proportions.

The situation with respect to the guaranteed composition of the brands on sale in Alabama is simplicity itself as compared with the figures for the four States already mentioned. There are 364 brands of complete fertilizers on sale

[a]Annual Report on Fertilizers, Aug. 1, 1908, Dept. of Agr., Montgomery, Ala.

in the State, of which 341 brands, or 94 per cent, have the following guaranteed composition:

Number of brands.	Phosphoric acid.	Ammonia.	Potash.	Number of brands.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
251	10	2	2	7	9	3	3
7	10	4	4	17	9	2	3
17	10	3	3	21	8	2	4
5	10	2	3	16	10	2	4

The formula 10: 2: 2 far outnumbers all others, being represented by 251 samples, or 70 per cent of the whole number.

The extreme range in composition in the 341 brands as shown above is 2 per cent phosphoric acid, 2 per cent in ammonia, and 2 per cent in potash. In the remaining 23 brands the phosphoric acid goes up in 3 cases to 12 per cent and down to 6 per cent in 2 cases. Potash goes as low as 1 per cent in 3 brands. These are the extreme limits in composition of the complete fertilizers sold in the State. There are practically no special brands for special crops except cotton. The revenue from the sale of fertilizer tags for the fiscal year 1907–8 is given as $93,748.

GEORGIA.

The Georgia department of agriculture discusses quite fully the compositions of fertilizers and their relation to crops, and actually gives a number of special formulas for special crops, without, however, claiming to base these upon exact knowledge.[a]

The following extract from the state fertilizer inspection law is interesting in this connection:

"SEC. 4. Be it further enacted that the words 'high grade' shall not appear upon any bag or other package of any complete fertilizer, which complete fertilizer contains by its guaranteed analysis less than 10 per cent available phosphoric acid, 1.65 per cent nitrogen (equivalent to 2 per cent of ammonia), and 2 per cent of potash, or a grade or analysis of equal total commercial value; that the word 'standard' shall not appear upon any bag or other package of any complete fertilizer which contains, by its guaranteed analysis, less than 8 per cent available phosphoric acid, 1.65 per cent nitrogen (equivalent to 2 per cent ammonia), and 2 per cent potash, or a grade or analysis of equal commercial value; that the words 'high grade' shall not appear upon any bag or other package of any acid phosphate with potash which shall contain by its guaranteed analysis less than 13 per cent available phosphoric acid, and 1 per cent potash, or a grade or analysis of equal total commercial value; that the word 'standard' shall not appear upon any bag or other package of any acid phosphate with potash which shall contain, by its guaranteed analysis, less than 11 per cent available phosphoric acid and 1 per cent potash, or a grade or analysis of equal total commercial value; that the words 'high grade' shall not appear upon any bag or other package of any plain acid phosphate which shall contain by its guaranteed analysis less than 14 per cent available phosphoric acid; and lastly, that the word 'standard' shall not appear upon any bag or other package of any plain acid phosphate which shall contain, by its guaranteed analysis, less than 12 per cent available phosphoric acid. It is hereby provided that no complete fertilizer, acid phosphate with potash, acid phosphate with nitrogen, or plain acid phosphate shall be offered for sale in this State which contains less than 12 per cent of total plant food, namely, available phosphoric acid, nitrogen when calculated as ammonia, and potash, either singly or in combination: *Provided*, That in mixed fertilizers there shall not be claimed less than 1 per cent potash and 0.82 per cent nitrogen, when one or both are present in the same mixture."

The following rulings have been made by the commissioner, based upon the inspection law:

Fourth.—In case of goods containing 10 per cent available phosphoric acid. 0.82 per cent nitrogen, and 1 per cent potash, or such mixture 9 : 1.65 : 1, or

[a] Commercial Fertilizers and Chemicals, Season 1907–1908, Serial No. 46, Ga. Dept. of Agr.

8 : 0.82 : 3, or other combinations which do not reach a total commercial value equal to that of the standard fertilizer, which is 8 : 1.65 : 2, such mixtures are not to be designated by any grade at all. Such goods may be offered for sale and branded with any name the market desires to give, provided such name does not indicate that they belong to a high or standard grade.

Sixth.—In the case of goods containing less than 1.65 per cent nitrogen they may be branded as "ammoniated" goods, "guano" or "fertilizer," or other words implying that the same is au ammoniated superphosphate, provided they contain not less than 0.82 per cent nitrogen.

Seventh.—A goods containing 10 per cent available phosphoric acid, 0.82 per ceut nitrogen and 3 per cent potash, can not be branded high grade, since it has not as high a commercial value as the legal high grade.

Eighth.—No manufacturer has the right to print the word "ammonia" at all on his sacks.

Sixteenth.—It is hereby ordered, in consonance with the spirit of section 8 of the law, that no cyanogen compounds, dried muck or peat, wool waste, tartar pomace, or Mora meal, or other material not recognized by scientific authorities as being available sources of plant food, shall be used in any fertilizer sold in this State. All manufacturers are warned against purchasing unfamiliar fertilizer materials without first inquiring of this department as to their character.

Under the title "Misleading brand names and a little advice on purchasing," the following occurs:

It shall be borne in mind always that state valuations are relative and approximate only, and are only intended to serve as a guide. It is much to be desired that farmers should study the analyses giving the actual percentages of plaut food more, and pay no attention whatever to names and brands.

They should realize, for instance, that in nine cases out of ten brands known as "pure dissolved bone" contain not a particle of bone, but are made simply out of phosphate rock. They are every "whit and grain" as good as if they were made from bone, the available phosphoric acid from rock being just as available and identically the same as the available phosphoric acid from bone. The proof that such brands are not made from bone is that they contain no nitrogen, and if they were made from bone the percentage of nitrogen would be stated, and would be charged for. This is only one instance of the folly of being influenced by names and brauds—many might be given.

Remember that a multiplicity of brands is also expensive to the manufacturer, and you have to pay the cost in the long run. Study the market, select a time for purchasing when general trade in fertilizers is dull, club together with some of your neighbors, and then order from a reliable manufacturer, stipulating, if you have a preference, just what materials the goods shall be made from, and especially the guaranteed percentage of nitrogen, phosphoric acid, and potash. Let the maker call it anything he pleases.

The following proportion of plant food element for special crops is recommended by the department, although the caution is given that "every intelligent farmer will study his environment, his soil, and climatic conditions, and then use his best judgment."

Crop.	Phosphoric acid.	Ammonia.	Potash.
	Per cent.	*Per cent.*	*Per cent.*
Cotton	10	6	3
Corn	8	3	5
Wheat	5	6	3
Celery	5	8.5	8
Potatoes	7	7	8
Beets and lettuce	5	7	8
Cabbage, cauliflower, cucumbers, and melons	5	7	5
Spinach	8	6	6
Radish and turnip	7	6	8
Asparagus	7	6	8
Eggplant and tomatoes	6	6	7
Onions	5	6	8
Sweet potatoes	7	3.5	8
Beans and peas	7	3.5	7

Coming now to a consideration of the composition of the brands actually on the market, we find on the whole an astonishingly small variation in percentage composition of mineral plant food elements, altbougb there is no possible way of determining how much variation there is in the material that went into the several brands.

There were 1,822 brands inspected, analyzed, and placed on the market for sale. Of these, 1,260 brands contain two or more plant food elements (phosphoric acid, nitrogen, or potasb) in 106 combinations. There are 26 combinations, however, embracing 1,143 brands, or 90 per cent of the total, in which each combination is represented by 6 or more brands. Of the 1,260 brands containing two or more elements, 1,259 contain phosphoric acid, and 1,163 brands, or 92 per cent, contain from 8 to 10 per cent of phosphoric acid, as follows:

Brands.		Percentage of phosphoric acid.
Number.	Percentage.	
563	45	10
180	14	9
420	33	8

Tbere are 77 brands, or 6 per cent, containing from 11 to 16 per cent, and 19 brands, or 2 per cent, containing from 7 to 5 per cent of phosphoric acid.

There are 1,259 brands containing potash, and 1,189 of these brands, or 93 per cent, contain from 1 to 4 per cent of potash, as follows:

Brands.		Percentage of potash.
Number.	Percentage.	
291	23	4
249	20	3
605	47	2
44	8	1

In addition to these, there are 54 brands, or 4 per cent, containing from 5 to 8 per cent of potash.

There are 987 brands containing nitrogen, and of these 947 brands, or 96 per cent, contain from 1 to 4 per cent of ammonia, as follows:

Brands.		Percentage of ammonia.
Number.	Percentage.	
34	3	4
85	9	3
696	70	2
132	14	1

In addition to these, there are 17 brands, or 2 per cent, containing from 5 to 8.9 per cent of ammonia.

There are 855 brands, or 89 per cent, of all the complete fertilizers in wbich tbe variation in composition is from 8 to 10 per cent phosphoric acid, 1 to 4 per cent ammonia, and 1 to 4 per cent potash, as follows:

Brands.		Percentage of phosphoric acid.	Percentage of ammonia.	Percentage of potash.
Number.	Percentage.			
255	27	10	3	2
242	26	8	2	2
90	9	9	2	3
44	5	10	3	3
34	4	10	1	3
28	3	10	2	4
23	2	8	1	3
23	2	10	1	1
23	2	9	1	2
18	2	10	4	4
18	2	8	2	4
18	2	9	2	1
14	1	9	3	2
13	1	9	2	2
12	1	8	3	3

Or, to put the matter in another way, there are 510 brands that differ only 2 per cent in the phosphoric acid, as follows:

Number of brands.	Percentage of phosphoric acid.	Percentage of ammonia.	Percentage of potash.
255	10	2	2
13	9	2	2
242	8	2	2

Then, there is in addition 254 brands in which the extreme variation from the above is 1 per cent ammonia and 2 per cent potash, as follows:

Number of brands.	Percentage of phosphoric acid.	Percentage of ammonia.	Percentage of potash.
28	10	2	4
8	10	2	3
34	10	1	3
1	10	1	4
6	10	1	2
1	9	2	4
90	9	2	3
2	9	1	4
6	9	1	3
23	9	1	2
18	8	2	4
8	8	2	3
6	8	1	4
28	8	1	3

It is apparent, therefore, that 764 brands, or 80 per cent, of the complete fertilizers sold in the State of Georgia have an extreme variation in composition—so far as the official records show, and the manufacturers' guaranty claim—of 2 per cent in phosphoric acid, 1 per cent in ammonia, and 2 per cent in potash. Furthermore, they are far below in ammonia and potash content the formulas proposed by the state inspection, as given on a previous page of this report.

The following is a list of the 255 brands having a guaranteed composition of 10 per cent phosphoric acid, 2 per cent ammonia (1.85 nitrogen), and 2 per cent potash:

List of brands having the guaranteed composition 10 : 2 : 2.

Athens High Grade Guano.
A A A A High Grade Guano.
Acid and Meal Mixture.
Acme High Grade.
Adair's Soluble Pacific.
Alligator Ammoniated Bone.
American High Grade Fertilizer.
10 : 2 : 2 Ammoniated Bone.
Ammoniated Dissolved Bone.
Ammoniated Dissolved Bone and Potash.
Anderson's High Grade.
A. N. Hay's Fish Scrap High Grade.
A. & T. Ammoniated Dissolved Bone.
Atlantic High Grade Ammoniated Guano.
B. & B's High Grade.
Baker's High Grade.
Baker High Grade.
Ball Ground High Grade.
Baugh's High Grade Cotton and Truck Guano.
Bear High Grade Beef, Blood and Bone.
" Big Crop."
Birmingham Blood, Bone and Potash.
Birmingham High Grade Fertilizer.
Black Hawk High Grade.
Black Jack High Grade Guano.
Blood and Bone.
Blood and Bone High Grade.
Blood and Bone High Grade Fertilizer.
Blood and Bone High Grade Guano.
Blood, Bone and Potash.
Blood and Tankage Mixture.
Bowker's High Grade Fertilizer.
Boyd's Acme Soluble.
Boyd's Animal Bone Guano.
Brer Fox Fertilizer.
Brer Rabbit Fertilizer.
Buffalo High Grade.
Burke County Fertilizer.
Campton High Grade.
Capitola High Grade Guano.
Carlton's Best.
Carter's Boll Maker.
C. F. Sasser's Choice.
Chattahoochie.
Cherokee Fish High Grade.
Cherokee High Grade.
Cherokee High Grade.
Chickamauga Fish Scrap Guano.
Chickamauga High Grade Fertilizer.
Chickamauga Peanut Food.
Climax.
C. O. and F. Co.'s High Grade.
Heard County High Grade.
Henry County High Grade Guano.
" High Grade."
" High Grade."
" High Grade."
High Grade Guano.
High Grade Fertilizer.
High Grade Fertilizer.
High Grade Guano.
High Grade Guano.
Hill Billy,
High Grade Ashepoo Fertilizer.
High Grade Bradley Soluble Guano.
High Grade Meal Mixture.
High Grade Victor Guano.
H. and H.'s High Grade C. S. M. Guano.
Hodge Home Mixture No. 3.
Holbrook Cotton Special.
Home Mixture No. 3.
Home Mixture No. 3.
Home Mixture No. 3.
Home Mixture No. 3.
Home Mixture No. 3.
Home Mixture No. 3.
Home Mixture No. 3.
Hoschton Pride and Big Indian Cotton Grower.
H. P. and B.'s Cotton Hustler.
Humber's Compound.
Independent High Grade.
Jackson County Favorite Cotton Producer.
Jacksonville High Grade Fertilizer.
Jasper High Grade.
Jefferson High Grade Complete Fertilizer.
Jefferson Meal, Acid, and Potash Mixture.
Jenkin's Special Blood Guano.
Jewell's High Grade Guano.
J. J. and B. L. Bond and Company's High Grade.
Jones Merc Co. High Grade.
Kirk's High Grade Fish Guano.
Knight's Special.
Langford's Best.
Legal Tender High Grade.
Lewis' High Grade
Lion High Grade Guano.
Lion Power Guano.
Lowry's High Grade Guano.
McCarty High Grade Corn Grower.
McCarty High Grade Cotton Grower.
McClure's High Grade Special.
McDonald and Weaver Acid and Meal.
McDuffie's High Grade Guano.
Mansfield Blood and Meal Formula.
Marriman's Cotton Boll.
10:2:2 Cotton Seed Meal Mixture.
Columbia High Grade Cotton Grower.
Coweta Fish Guano.
Coweta High Grade Fertilizer.
Compound Guano.

Cooper's High Grade.
Cooper's High Grade Guano.
Cotton Grower.
Cotton Meal Special.
Cotton Success.
Cotton Tail.
C. P. Lively Son's High Grade.
10:2:2 C. S. M. Mixture.
Davis High Grade Guano.
Daybreak Fertilizer.
Delaware River High Grade Fish Guano.
Eagle High Grade Guano.
E. B. Clark's Cotton Grower.
Empire High Grade Ammoniated Dissolved Bone.
Empire State Blood and Bone.
Etowah High Grade.
Eureka Ammoniated Bone.
Eutaw High Grade Golden Fertilizer.
Farm Bell High Grade.
Farmers Choice.
Farmers Choice.
Farmers Friend.
Farmers High Grade.
Farmers Soluble High Grade.
Farmers Special Number 4.
Farmers Success.
Fayette Company High Grade.
Felton's Favorite.
Fish Compound.
Flannery's Staple Upland Cotton Grower.
Fowler Brother's High Grade Guano.
Fox Favorite.
Ft. Valley No Filler.
Furman's Fish Guano.
Furman's High Grade Fertilizer.
Georgia High Grade.
Georgia High Grade.
Georgia Keystone.
Georgia Test High Grade.
Gibb's Special Cotton Guano.
Gilt Edge High Grade Guano.
Gossett's Blood, Bone, and Meal.
Governor Guano.
Green County Oil Company's High Grade.
Green and Shadburn High Grade.
44 High Grade Guano.
Hammock's High Grade Formula.
Hampton High Grade Guano.
Mastodon Ammoniated Soluble Phosphate.
Maxwell's Favorite.
Mississippi Sawyer.
Monarch Guano.
Moore's Special Pride.
Mortgage Killer.
Mortgage Lifter.
Navassa High Grade Fertilizer.
Neely's Burke County Fertilizer.
Newton County High Grade Guano.
North Georgia Pride.
N. and N's High Grade Ammoniated Guauo.
Ober's Special Ammoniated Dissolved Bone.
Oil Mill High Grade Fertilizer.
Old Domian High Grade Guano.
Old Time Fish Scrap Guano.
Oliver's Acid, Meal, and Potash.
Oostanaula High Grade Blood and Bone.
Orange High Grade.
Our Union Ideal.
Owen's High Grade.
Ox Grade Ammoniated Boue.
Ox High Grade Fish.
Patapsca Guano.
Paulding County High Grade.
Paullins' Blood and Bone.
Pelican Guano.
Planter's High Grade.
Planter's High Grade Fertilizer.
Planter's Pride.
Planter's XXXX High Grade Blood, Bone, and C. S. M.
Plow Share Brand Guano.
P. N. P's Complete High Grade Guano.
Pride of Fayette.
Pride of Morgan.
Read's Full Boll.
Read's High Grade Ammoniated Dissolved Bone.
Read's Special Compound C. S. Meal.
Red Cross High Grade Guano.
Red Elk High Grade No. 2.
Redwine's Special.
Rex High Grade.
Romulus High Grade Guano.
Royal High Grade Guauo.
Royal Seal Guano.
Royster's High Grade Soluble Guano.
Roystou High Grade.
Salmon's High Grade.
Sam Bowers' Acid, Meal and Potash Mixture.
Sam Bowers' High Grade.
Savannah Oil Mill High Grade Fertilizer.
Scott's Gossypium Phosphate.
Seabird High Grade Guano.
Senora High Grade.
Shirley's High Grade.
Smith's High Grade Blood and Bone.
Southern High Grade Fertilizer.
Special Mixture.
S. P. Thompson's High Grade Guano.
S. S. Grant High Grade Cotton Pusher.
S. S. Old Peruvian.
Stafford's Blood and Meal.
Stafford's High Grade Guano.
Strickland's High Grade.
Superior Meal Mixture.
Swift's Eagle High Grade Guano.
The Troup Company's Blood and Bone.
The Troup Company's Ocean Fish Scrap.
Three States High Grade Soluble Guano.
Tonawanda Guano.

Tuscarora Big Crop Fertilizer.
Uncle Joe High Grade.
Uncle Remus' High Grade Guano.
Uncle Sam High Grade Ammoniated Guano.
Uruguay Ammoniated Bone.
Union Ideal Guano.
Upson County High Grade.
U. S. Meal Mixture.
V. C. Chesapeake Fish Guano.
V. C. High Grade Fish Guano.
V. C. Special High Grade Meal Fertilizer.
Vidalia Gold Medal Fertilizer.
Walton High Grade.
Warrior High Grade Complete Fertilizer.
W. A. Shore's High Grade.
W. D. Hawkins' High Grade Guano.
W. and H's Golden Union.
Wilson's Cotton Grower.
Wiuder High Grade Guano.
W. O. C., a pure Blood Guano.
Woods High Grade.
W. and T. High Grade Cotton Special.
Yellow Jacket Guano.

OBSERVATIONS ON THE DATA.

While the Georgia state department of agriculture recommends that from 200 to 500 pounds of fertilizer be used per acre, it may be safely said that the amount applied by the great majority of farmers is about 200 pounds per acre. Out of the 764 brands, such an application would add from 16 to 20 pounds phosphoric acid, 2 to 4 pounds ammonia, and 4 to 8 pounds potash to an acre.

If we assume that this fertilizer goes into immediate and complete solution and is distributed in the soil moisture to a depth of 6 inches from the surface, and if we assume further that the weight of an acre of soil 6 inches deep is 2,000,000 pounds and contains on the average 15 per cent of water, the maximum effect on the concentration of the soil moisture, diregarding the effect of the fertilizer on the solubility of the soil minerals and the absorbing power of the soil, will be approximately as follows: Phosphoric acid, 53 to 67 parts per million; ammonia, 7 to 13 parts per million; and potash, 13 to 27 parts per million.

So far as the ammonia and potash are coucerned, these concentrations are comparable with the normal concentrations of the soil moisture; for phosphoric acid the figures are considerably higher.

It may be assumed that in a majority of cases when used an application of 200 pounds of commercial fertilizer increases the productivity of the soil. An application of 400 pounds or 600 pounds is undoubtedly more efficient, and successful applications up to 3,000 pounds per acre are employed on tobacco, truck, and other special industries.

What immediately concerns us here, however, is the differences in composition in the brands of fertilizers sold and the relative efficiency of these brands when applied to any particular field or crop. We have seen that of the 987 brands of complete fertilizers sold in Georgia markets, 255 brands, or 27 per cent, have the composition 10 : 2 : 2. Several of the dealers and manufacturers put out 6 or 8 more brands of this same composition. Do they differ and have different effects on the soil, and are they more efficient in connection with different crops? Under the state law and trade conditions they virtually have to be sold for the same price per ton. Officially, and so far as the public have certain knowledge, these 255 brauds are all one and the same thing, and yet in all probability most of them differ in some essential character in composition and effectiveness, by reason of the material contained or mode and condition of mixture. We know that the different carries of phosphorus, nitrogen, and potassium have very different effects on soils and crops, and the time has come when it would be an advantage to the farmer, and equally to the manufacturer, to determine more nearly the relative effect of materials on soils and crops rather than to pursue longer the study of the elements—for after all it is the material which counts rather than the elements which go to make up the material. That is to say, it is not the potash but the potash salt. There are nitrogenous bodies and potash salts both extremely toxic to plants, but of the common materials which can be safely used for crops, some are more efficient on some soils and some on others, and more should be known about such matters.

Contrast now with 255 brands of the composition 10 : 2 : 2 the 242 brands of the composition 8 : 2 : 2, making together more than half the brauds of complete fertilizers sold in the State. Is there a real difference in effect of these two classes due to the difference of 2 per cent of phosphoric acid? Or put the case more strongly still. Take the extreme limits in composition on the great majority (80 per cent) of fertilizers sold in the State, as given above.

This would probably be 10 : 1 : 2 and 8 : 2 : 4, or we might take 10 : 2 : 4 and 8 : 1 : 2. The difference in the actual amount of nitrogen and potash is 100 per cent; and to make the same application double the amount of fertilizer would have to be applied in the one case than in the other. The difference is much less in the case of phosphoric acid, but apart from the question of the actual amount, does the difference in proportion shown by these small quantities have an appreciable effect on the soils and crops? In the above formulæ for example, as extreme cases, we might apply 2 pounds per acre of ammonia with either 4 or 8 pounds of potash, or we might apply 4 pounds of ammonia with either 4 or 8 pounds of potash. Would these proportional and actual differences show in their relative effect on the soil and plant? We have reason to believe from laboratory and greenhouse experiments in growing plants in solutions of pure cultures and in soil extracts that they would, but we do not know enough about it, and it is in this direction that further investigations should be made to bring some order out of the problem of the practical application of fertilizers.

AGRICULTURE AS A NATIONAL ASSET.

By Dr. B. T. Galloway,
Chief of Bureau of Plant Industry, United States Department of Agriculture.

SUMMARY.

The latest available figures show that the land area of the United States is, in round numbers, nearly 2,000,000,000 acres. The area in farms is approximately 850,000,000 acres, or 45 per cent of the total land. Irrigation, drainage, and utilization of arid and semiarid lands will probably make available for future usc fully 50 per cent more land, or approximately 400,000,000 acres more.

The total wealth produced from the land in 1907 was, in round numbers, $7,500,000,000. As compared with the year 1899, the increase is 57 per cent. The increase in prices of farm products since 1900 is 37 per cent; the increase in prices of all commodities for the same period is 29 per cent; the increase in the value of farm land from the year 1900 to 1905, inclusive, is $6,131,000,000.

For the past five years the exports of agricultural products aggregated $4,565,000,000, reaching a maximum in 1907, when the value of the exports was $1,055,000,000.

The latest available figures show in the United States 6,000,000 farms. On 50 per cent of these farms production is falling off; on the other 50 per cent production is increasing. The average production of all crops has been increasing for forty years. Ninety per cent of the total increase in yields is brought about by 10 per cent of all the farmers.

Not less than 75 per cent of all the farmers in the country are engaged in some form of exploitive agriculture; that is, 75 per cent of all the farmers are taking from the land more than is being put back. Soil exploitation is an economic necessity in any new region or country and will continue where industrial pursuits other than agriculture are not encouraged, supported, and advanced. An equilibrium of industries means national prosperity. As an economic fundamental, selling must be accompanied by buying.

The wealth per capita of the farmer, the value of his land, his ability to select crops and systems of farm management, his power to supplant hand labor by machinery, and his ability to continually and profitably grow crops and at the same time build up and maintain the fertility of the soil arc all directly dependent upon the mutual relation of agriculture to other industries. A constructive policy, therefore, for all industries means a constructive policy for agriculture.

The annual wastes from the farm aggregate an amount equal to the annual products, viz, $7,500,000,000. Wastage of soil fertility through erosion, the losses caused by insects, diseases, and other enemies, the losses through misdirected labor, lack of proper capitalization, lack of cooperation and organization in the selling of things produced and the buying of things used on the farm, lack of adaptation to environment or inability to shift crops and practices to changing economic conditions, and lack of knowledge and experience in handling, storing, and transporting corps, are some of the direct and contributing causes of the wastes in question. These wastes are a natural concomitant of our rapidly shifting economic conditions. With the development of other industries and increased population, larger demands for agricultural products and keener competition, the wastes will gradually disappear.

Every type of agriculture, from soil mining by individuals and organized groups of individuals to well-balanced, profitable, and constructive systems, is to be found in this country. The extremes cited are practiced through lack of knowledge and because under existing economic conditions both are found profitable in their respective localities.

Agricultural production in the United States will increase as rapidly as profits justify and the individual farmer shifts his methods and practices in conformity with better knowledge of the economic changes now taking place. The potentialities of production, through improved systems of farm management and increased efficiency of crops as the result of breeding, selection and adaptation, cooperation and organization in buying and selling, utilization of machinery and horsepower, prevention of direct wastes, etc., are sufficient at the present time to double the yields without any increase in acreage.

The problem at hand is not an increase in the number of farmers so much as an increase in the efficiency of the individual farmer and the maintenance of the proper relations between the labor of the farmer and that of other industrial pursuits. If 30 per cent of the labor of the country were engaged in agriculture it would tend toward higher efficiency of the farmer, better prices, better methods, and less direct waste than a larger percentage. A greater efficiency of the farmer and the consequent reclamation and conservation of the natural resources with which he comes in contact may be brought about by proper education, efficient organization, and effective cooperation. Proper education, organization, and cooperation means socializing rather than individualizing the farmer; the broadening of the training of the children of both city and country to the end of creating a just appreciation of all industries.

It means not only the full support of the state in bringing home to the individual farmer all the information that will make the land more productive, but the full support of the state in making the farmer a part of the world movement for social uplift. There are now many forces working to this end and these forces are constantly growing in power and influence. The moment is at hand for a constructive policy having for its object the federation of these forces through a properly equipped and organized federal agency.

AGRICULTURAL PRODUCTION WITH SPECIAL REFERENCE TO CROP RESOURCES.

By Albert F. Woods,
Bureau of Plant Industry, United States Department of Agriculture.

In discussing the question of agricultural production from the standpoint of the maintenance of our natural resources, we have to consider, first, those natural factors which are modified, either in the direction of improvement or deterioration, by their use, namely, plants, animals, and the soil, and possibly tools and methods; second, those economic and social conditions which stimulate or suppress the cultural effort and ability of men. This paper will deal briefly with the origin, status, and potentiality of our crop resources. Agriculture has been developed by man in proportion as his needs and desires have exceeded what nature unaided supplied.

PLANTS.

The origin of most of our staple cultivated plants is now believed to be fairly well known [a] and is in most cases of great antiquity. The wild races from which they were selected have in most cases been discovered, aggregating altogether approximately 300 species divided among a considerable number of genera. The list does not include quite a number of American wild fruits and grasses which have come into cultivation within recent years. Practically all of the older cultivated species, however, have been widely scattered over the earth, and have become broken up into a very great number of mutations or variations, some of them sufficiently marked to almost make them new species, if not genera. These selected and cultivated mutations have been handed on from generation to generation, undergoing constant selection and modification as the result of it, until now the number of forms or varieties is very great and represents adjustments to a great variety of climates, soils, cultural methods, uses, and other natural and artificial factors of environment where men have lived.

While the specific relationship of a crop plant is of great importance as indicating its possible range of adaptation, these modifications and adjustments to particular conditions are of far greater agronomic value. These modifications, while not usually considered by botanists as anything more than " place effects " and artificial produc-

[a] See general table of species, with their origin and the epoch of their earliest cultivation; taken from Origin of Cultivated Plants, by De Candolle, pp. 436–462, inclusive.

tions, varieties or strains, are, nevertheless, of the greatest importance to man, as they enable him to live in places often otherwise uninhabitable and furnish material for food and clothing far superior to that obtainable from wild unimproved species. The only object in the life of the wild plant is to grow and reproduce itself, and no energy is lost beyond that necessary to insure this end. When the plant is brought under cultivation, the object is to increase some part of it in quantity or quality, or both, to meet some special need, and this is accomplished within certain limits in proportion to the duration, degree, and intelligence of the selective effort. The most valuable varieties of any crop plant for a locality are those which, as a result of long culture and selection in that locality, have adjusted themselves to the environment without losing their valuable qualities. In the case of cultivated plants, this adjustment is brought about in part by natural selection and partly by artificial selection. In the wild state, through countless generations of variation and natural selection and survival of the fittest, species and their varieties have become adjusted to the conditions under which they had to grow, the principal determining factors of growth being moisture and temperature range or fluctuation of the air and soil, the composition of the soil, disease and insect pests, competition with other species, etc. The power which the plant possesses to adjust itself to these conditions is a matter of the greatest importance, and the range within which a species or variety has the power of adjustment is limited. Crops, therefore, often differ in their relation to each of these factors and their combinations. Each species or variety is adapted to a certain combination and range of these conditions and reaches its best development only where the particular conditions to which the variety is adjusted are naturally or artificially supplied. When any condition varies beyond the limits of this adjustment the crop suffers in some particular correspondingly, and that condition becomes a limiting condition to that particular variety or strain.

These physiological adjustments have not been carefully studied and measured for most of our crop plants and are generally recognized only in their broader relations. No one would attempt the commercial culture of cotton in South Dakota, but many growers buy their cotton seed from southern Texas or Louisiana for culture in northern Texas or Oklahoma, with the result that the long-season adjustment of the southern seed does not fit the shorter season farther north and much of the crop is destroyed by early frosts. Cotton or corn adjusted to the poorer uplands in Texas will go largely to stalk if planted on the richer, moister river bottoms. On the other hand, varieties adjusted to give a balanced growth on the bottom lands fail to give good results on the poorer and drier uplands. In very dry years, however, the upland varieties may do better on the bottom lands than the bottom-land varieties, and in very wet years the bottom-land varieties may succeed better on the uplands than the upland varieties.

As a crop approaches its limits with regard to any factor, the influence of the other factors, which tend to intensify or compensate the reaction to the limiting factor, becomes increasingly important. A variety of corn which can barely mature in the crop season of North Dakota and Minnesota is made more certain if planted on warm, well-drained soil and given very thorough culture. If the soil is heavy and cold or poorly drained, or the crop is planted late or poorly cultivated, it may suffer from early frosts. Farther south, with a longer growing season, so far as the temperature limiting condition is concerned, the crop might do better on heavier, moister soil.

In nature related species often live under quite different conditions, certain species being adapted to different ranges and combinations of limiting factors, such as heat, moisture, drought, etc. It is often possible, therefore, by hybridization to produce species having intermediate characters or combining certain characters belonging to one species with certain characters belonging to another species in order to secure a variety adapted to conditions and uses to which neither of the species separately is adapted. When man began to select and cultivate wild species for his use, he, of course, started where he found the species growing wild, and had therefore a mixture of varieties corresponding to the wild forms. His first desire was to obtain a larger yield of fruit, seed, stem, leaves, or root, and he selected those individuals for seed which gave him the most in return for the care he could give them. They thus retained their natural vigor and resistance to limiting factors in their environment along with their specially selected characters. This is well illustrated in the strains of Indian corn as cultivated by the Indians at the time America was discovered and as grown by them still in Mexico and in Central and South America. It is also true of the cottons grown in the same countries. These aboriginal types still retain a wide power of variation, adaptation, and resistance to limiting conditions of their environment, especially where they have been cultivated for long periods exposed to those conditions. According to Cook,[a] many of these Indian tribes of Central America "are peaceable and sedentary, with highly developed agricultural instincts, which attach them closely to the land their fathers cultivated, and there is no reason to suppose that any very different condition existed in earlier times." It is thus evident that these aboriginal cottons and corns have been cultivated for long periods practically under the same conditions of seminatural selection. The characteristics and value of these varieties will be discussed later. The corns and cottons now in cultivation in the United States are selections and adaptations of some of these varieties, originally brought into the country by the Indians. They still retain a wonderful degree of adaptability and variation, which can be controlled in a very large measure by intelligent and long-continued selection.

In the Old World the same phenomenon is exhibited in the case of crops grown by the great masses of poor people, who have been obliged to live for long periods of time under conditions often extremely unfavorable and whose main object in life was to produce enough food to pay tribute with and to feed their families. Generation after generation lived under the same conditions, carefully saving every straw and seed. When some great drought or blight destroyed most of their crop the few remaining plants were not neglected and destroyed, but were carefully saved for seed, as it was often not possible for these poor people to obtain an outside supply. Thus, as a result of centuries of such selection and survival of the fittest, we

[a] Cotton Culture in Guatemala, by O. F. Cook, Yearbook, U. S. Dept. of Agr., 1904, and Bureau of Plant Industry Bull. No. 88.

find these poor people possess varieties extremely resistant to the severe limiting conditions under which they were forced by necessity to live. A frequent change of seed, of location, or of economic conditions that would have permitted less careful saving of seed would have lost to the world these valuable products of unconscious natural selection.

As civilization advances and economic conditions improve men often become more careless in the matter of seed selection. If cold or drought or disease causes a failure of the crop, the few straggling plants remaining are destroyed and seed for the next crop is secured in the market, with no knowledge of the conditions under which it was grown. It is, therefore, usually a mixture of seed from different sources, having been grown under conditions sufficiently different so that in a new locality the plants must go through a process of variation and adjustment before they will give satisfactory returns, but as a result of the same careless methods the plants never get a chance to become adjusted to the new conditions. The process of adjustment is mistaken for deterioration or so-called "running out," which in reality is the case where intelligent selection is not practiced. These careless methods have characterized the agriculture of the United States up to very recent times. The greater number of our farmers have given little or no attention to sources of seed or to intelligent seed selection. The rule is to sell the best and plant the culls, which, of course, is selection in the direction of deterioration. As a result of this, complaint is constantly being heard of varieties running out.[a] Many seedsmen have also been guilty of the same careless methods in buying and selling seeds of the great staple forage and cereal crops. Experimenters have also in most cases overlooked these fundamental facts of acclimatization and adjustment in the introduction and testing of new crops, and many a valuable plant resource has been pronounced worthless because it has not been adjusted to the particular conditions under which it was being tested. These adjustments are often physiological and may not change the general appearance or structure of the variety, but are apparent only in its response to the conditions of environment and culture. It is easy, therefore, to substitute such varieties for each other or to overlook them entirely, whereas, with a little careful observation, some of the mutations resulting from the attempt of the plant to adjust itself to its new conditions might prove to be well adapted to the new conditions and produce profitable crops if carefully selected.

As the demands made on the farmer are more exacting and he is rewarded in appreciation and money return for greater care, he rises to the situation. As the agriculture of the country settles down to more definite lines and to a more stable condition, these careless methods will disappear, and in fact have been rapidly disappearing in the past twenty years. This has been most apparent in the selection and improvement of flowers, fruits, and vegetables grown for our best markets. The development of fine varieties, and the care with which they are grown and marketed, has reached a point of the

[a] While failure to properly select is the cause of the real deterioration of varieties, the disappearance of old forms is also due to the development of better varieties, the old forms, therefore, being neglected in favor of the better strains. This is also responsible in part for the idea of the running out of varieties.

highest excellence in this country, owing to the appreciation of excellence and the high price which our cities are willing to pay for it. In the region of our great markets, like St. Louis, Chicago, Philadelphia, and New York, and the trucking lands tributary to them, the investment in the production of such crops and the annual returns aggregate several hundred million dollars. There have been also, since the earliest settlement of the country, here and there individuals who have taken an interest in the selection and improvement of our staple crops—corn, wheat, cotton, oats, rye, barley, etc.—and many new and improved varieties have been introduced, and have given good results when grown under conditions to which they were adapted. These plant resources are the foundation of our agriculture, and are of more value to us than any other natural asset.

It will now be desirable to briefly review our principal plant resources.

INDIAN CORN.

Indian corn is the most widely cultivated and the principal crop plant of the United States. It is a native of tropical America, where a large number of varieties exist, many of which were adapted to conditions (including extremes of moisture, drought, and high altitude) under which the varieties now planted in the United States do not thrive. It is believed that some of these strains will be valuable, either on their own account or for hybridizing purposes with the strains we now have, in order to better adjust them to conditions where corn culture is now uncertain.

Prolonged production of pollen.—One important adaptation of these drought-resisting types of corn is the greater length of time during which pollen is produced. Although the tassels are much smaller than in our United States varieties, the same tassels continue to yield pollen for a period of several weeks, whereas our varieties may supply pollen for only as many days in dry localities or dry seasons. This character furnishes a protection against the loss of a crop through the occurrence of extremely dry, hot weather at the time of flowering, and may have much practical importance in the region to the south and west of our present corn belt, where the growing of our American varieties is prevented by dry climate and hot winds. In fact, the destruction of the pollen by drought and hot winds has been the cause of greatly decreased yields in the center of our corn belt, in Illinois, Iowa, Missouri, Kansas, and Nebraska. If greater drought-resisting qualities could be bred into some of our high-yielding strains of dent corns it would be of immense value, and there is no doubt that this can be accomplished. A study of the fluctuations in yield in the great corn States of the Ohio Valley, upper Mississippi and Missouri valleys, and the Great Plains shows that drought and hot winds are the principal limiting conditions to corn culture, and are often prolific causes of reduced yield. As will be seen by examining the table of annual yields, the great reductions in yield have been in years of severe drought during the growing season, and in those States or parts of States where the drought was most severe the yields have, of course, been lowest. (See article on this subject by the present writer, p. 227.)

In western Nebraska, Kansas, and the Dakotas the annual rainfall is usually not much greater than actually required for the production of average crop yields, and is the principal limiting factor of crop production in that region. The evaporation in the southern part of this area as compared with the northern part is nearly double, so that with the same rainfall the amount of available moisture for a crop will be much less in the southern than in the northern part of the Great Plains. With the same rainfall, therefore, we find the crop yields in the south of this area much less than in the north, owing to the fact that more of the water that falls remains in the soil in the north. The difference between the moisture-holding capacity of soils and the cultural methods adapted to conserve moisture is also brought out clearly in this western region in dry years. Where the soil has been prepared in the fall so as to absorb winter rainfall or melting snow, and cultivation methods have been adopted so as to conserve this water in the soil for the use of crops, good yields are often secured with very small summer rainfall, or, in some cases, even none at all. The different preparation of the soil and cultural methods are often apparent on farms side by side—one farmer raising a good crop on soils where the moisture has been conserved, and his neighbor, who has not followed proper cultural methods, having a total failure. The difference between varieties of plants adapted to growth under dry conditions and those adapted to moist conditions is also here clearly demonstrated.

While the effect of drought on yield is most marked as we approach the limits of available moisture, it is also considerable in the regions of normally heavier rainfall. Under careful experimental conditions at the Illinois Experiment Station, the average yield of 18 varieties was 29.4 bushels in 1887, 83.2 bushels in 1888, and 66 bushels in 1889. Meteorological conditions appear to have been largely, if not solely, the cause of these differences in yield.[a] The average yield for Champaign County, in which the experiment station is located, in 1887 was 20 bushels; in 1888, 42 bushels; in 1889, 35 bushels. The difference between these average yields in the county and at the station may be fairly considered to represent the difference between the best standard culture and the average culture, while the fluctuation between years shows the effect of season, 1887 being a drought year.

Similar fluctuations occurred during the drought of 1894. The average for the northern division of Illinois was 31 bushels, the lowest yield being 15 bushels in Lake County. The average for the central division was 35 bushels, the lowest being 10 bushels in Coles County, and the highest 50 bushels in Calhoun. The average for the southern division was 18 bushels, with a minimum of 3 bushels in Bond County and a maximum of 28 in Madison County.

The soils of northern and central Illinois are much better adapted to absorb and retain moisture than those of the southern part of the State, and the relative evaporation follows the same law as indicated farther west, so that a study of crop yields, even with the same rainfall, in the northern and southern parts of the State shows less effect of drought in the north and greater effect in the south under otherwise the same conditions, the effect, of course, being intensified where the soil is favorable or unfavorable to moisture absorption and retention, and increases in yield also being secured in dry years by those cultural methods which tend to conserve moisture.

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[a] See Abbe, Climate and Crops, p. 334.

In the Southern and Southeastern States, in the cotton belt, where yields are very low as a rule, the moisture factor also plays a considerable rôle. Although the rainfall is much higher than in the northern belt, it evaporates quicker, and the soils as a rule are less retentive of moisture, being in most localities depleted in humus. According to A. J. Henry,[a] "the smallest amount of rainfall that may be expected in the great corn and wheat regions of the central valleys does not vary greatly from 9 to 10 inches (from April 1 to September 30). In the South Atlantic and Gulf States the fall in the year of least rain ranges from a maximum of 20 inches in central and northern Florida to less than 15 inches in the Mississippi Valley and a considerable fringe of country to the westward. The amount of rain that falls in the year of severe drought in the greater part of the Southeastern States is sufficient for the growth and maturity of staple crops, if properly distributed. Success in agricultural pursuits, so far as conditioned upon the rainfall, should therefore be more easily achieved in the Southeastern States than elsewhere, particularly in regions of precarious rainfall." The shallow spring plowing characteristic of the cotton States is not adapted, however, to conserve the water that falls, so that there is seldom a year in which crops do not suffer more or less from drought. The general character of the rainfall of the Southeast is conducive to the development of rather soft growth, evaporating water with considerable rapidity, so that any lack of moisture at the roots is much more evident and injurious than would be the case where the air is drier normally. Experiments conducted through the southern area by the Department of Agriculture and the state experiment stations have shown conclusively that deep plowing, the use of barnyard manures and legumes or other green crops to increase the decaying organic matter and humus of the soil, with shallow summer cultivation, are alone sufficient to raise the average yield of corn in these States to the average of the best corn States.

American strains of corn.—From whatever types in Central America or South America our varieties of corn now in cultivation may have come, we now have in our great central corn belt numerous strains or adaptations of the greatest value. Some of these have become fairly well known, but there are many others which have been grown in certain localities for many years which simply require a little careful selection to bring out their highest yielding capabilities. The corns that we now have fall into six generally recognized groups, as follows: Pop corns, flint corns, dent corns, soft corns, sweet corns, and starchy sweet corns. All of these have their valuable features and uses. The flints and pop corns are generally considered to be cool-region corns, having been grown successfully as far north as Quebec. The flint corns were first introduced and cultivated in the North Atlantic region by the Indians, and has remained to the present time the principal type cultivated in New England. These northern flint strains have thus become adapted to the short seasons of the North. Similar flint varieties, however, were also grown by the Indians in the central and southern localities, in the

[a] A. J. Henry, Rainfall of the crop season, Yearbook, U. S. Dept. Agr., 1897, p. 617.
See also Relation of precipitation to yields of corn, Yearbook, U. S. Dept. Agr., 1903, pp. 215–224.

Gulf region, and Central and South America, the southern forms having a longer growing season. The flint varieties are lower yielders and less desirable in other characters than the dents.

The dent varieties are generally considered to be longer season sorts and have been cultivated generally south of New York, Minnesota, and the Dakotas. On account of their better quality and higher yielding power, they have been gradually pushed north into Minnesota, Wisconsin, and the Dakotas, and as a result of careful selection high-yielding strains maturing in ninety to one hundred days have been secured. One ninety-day type, bred by the Department of Agriculture in Wisconsin and Minnesota, has yielded as high as 90 to 100 bushels of shelled corn per acre in field tests. A strain developed in Connecticut from Illinois seed of Reid's Yellow Dent has been selected at Hockanum, Conn., since 1905. Very few ears matured in 1905. These were saved and planted in 1906 and practically all the crop matured, yielding 121 bushels of mature shelled corn per acre—more than double the yield of flint corn grown under exactly the same conditions. It is evident, therefore, that high-yielding, quick-maturing dent corns can be developed by careful selection for the colder Northern States.

A similar high-yielding strain of white dent was developed by a farmer near Gainesville, Ga., by planting together four varieties of dent and allowing them to cross. A strain was selected showing evidence of being a cross, which after a few years' selection under the Georgia conditions has proved to be one of the finest dent strains yet developed, yielding from 75 to 100 bushels of shelled corn per acre in field tests, some of the ears weighing over 2 pounds. This is more than double the yield of the unselected dent varieties of the same region grown under the same conditions, and from seven to ten times the average yield of the State.

A number of important selections have been made from time to time which have had an important influence on corn culture, especially in the upper Missisippi and Missouri valleys. Among these may be mentioned the following: Leaming, a deep yellow dent, selected by J. S. Leaming, Wilmington, Ohio, in 1826; Reid's Yellow Dent, selected by J. L. Reid, Delavan, Ill., in 1846; Golden Eagle, a yellow dent, selected by H. B. Perry, Toulon, Ill., in 1871; Boone County White, selected by James Riley, Thornton, Ind., in 1876; Riley's Favorite, a white dent, introduced by James Riley in 1885; Pride of the North, a white dent, introduced by F. A. Warner, Sibley, Ill., 1890. These were principally selections of good individuals of the various types in common cultivation in the region, some of them probably resulting from crosses of different strains. Corn being pollinated by wind-borne pollen, the varieties, of course, often cross, which causes considerable variation and increased vigor. By selecting the best individuals and growing them by themselves for several generations fairly pure types can be developed of much greater producing power than the average. Every strain, however, must be developed under the same conditions in which it is to be grown in order to get the greatest returns from it. This adjustment readily takes place as a result of a few years of intelligent selection.

Investigations and demonstrations carried out in all sections of the United States by the Department of Agriculture and the state experiment stations have shown beyond a doubt that the present average yield of corn per acre could be doubled, with practically no increase in work or expense, by giving careful attention to seed selection and vitality and cultural methods. In our principal corn-growing States corn is planted $3\frac{1}{2}$ feet apart each way, making 3,556 hills per acre. Three stalks to a hill is considered a perfect stand, and with good, vigorous seed it is not difficult to secure on an average three good healthy stalks. If one in three of these stalks produces a small 6-inch or 7-inch ear weighing only a little over 9 ounces, the yield would be 28.8 bushels to the acre. This is the highest average yield for the United States, and occurred in 1905. This, of course, is an exceedingly small amount of grain to secure from three stalks. The average yield for the past forty years has been 25.2 bushels. New Hampshire and Vermont have averaged 35 bushels, fluctuating from 21 bushels in years of drought to 45 bushels in the most favorable seasons, and have shown a gradual increase from 1867 to date. The yields for Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, and Iowa have averaged from 31 to 33 bushels for the entire forty years, fluctuating from about 20 bushels in the driest years to about 40 bushels in the best years. Missouri, Nebraska, Kansas, Kentucky, and Tennessee follow slightly below the States just mentioned, the fluctuations, however, being greater in those States more subject to drought, falling as low as 7 to 10 bushels in Kansas and Nebraska and running as high as 42 to 43 in the same States. The lowest average yields are in the Southern States: Virginia, 19.2 bushels, fluctuating from as low as 13 bushels in dry years to as high as 25 in good years; North Carolina, falling as low as 9 bushels in dry years and running up to 16 bushels in favorable years; South Carolina, falling as low as 6.9 bushels in dry years and running up to 12 bushels in good years; and similar low yields in Georgia, Florida, Alabama, Mississippi, and Louisiana; Texas and Arkansas being a little higher.

The most careful selection of seed has been practiced in Illinois, Indiana, Nebraska, and Kansas, but even in these States the work has not continued long enough to be definitely brought out in general statistical data, but the difference is easily ascertainable in comparing individual growers who use selected seed and good methods with those under the same conditions using ordinary seed and ordinary methods. Good growers who carefully select their seed often obtain a yield of 80 to 100 bushels of shelled corn per acre. It is easy to produce strains that will average three or even four 9-ounce ears per hill of three stalks, but these are very small ears, and strains are very easily developed which produce ears averaging a pound, some of the ears running up to $1\frac{1}{2}$ or 2 pounds. This average is frequently reached and exceeded under identically the same conditions of soil, climate, and culture that with ordinary strains give 40 to 50 bushels or less per acre. With careful attention to seed selection and testing,[a] still greater average production for the United States could be reached with little additional cost and greatly increased profits even at present prices.

It is not argued, however, that it is desirable to make any such increase in the total production as this would imply, as the present production is about equal to the demand. An excess over ready demand has a tendency to reduce prices, which is followed by re-

[a] See Farmers' Bulletins N[illegible] 100, 229, and 253, U. S. Dept. Agr.

duced acreage the next season, with a gradual rise in price, followed by increased acreage again. This fluctuation is shown by the tables on yield and prices of corn in the 1907 Yearbook of the Department of Agriculture.[a] However, if one acre could be made to produce as much as two do now, the other acre could be devoted to some other paying crop. Just as much corn would then be produced as at present, with the cost of production per bushel greatly reduced, and the profits, therefore, at present prices greatly increased. It costs little more to plow, harrow, plant, and cultivate an acre for a 100-bushel crop than it does for 40 bushels, and the land tax and rent are the same. These are the heavy fixed charges. Accurate data on the cost of production of farm crops are scarce. The most carefully secured information is to be found in Bulletin 48 of the Bureau of Statistics, U. S. Department of Agriculture, and Bulletins 97 and 109 of the University of Minnesota Agricultural Experiment Station. The following tables are taken from Bulletin 97 of the Minnesota Experiment Station:

Cost of producing corn—ears husked from the standing stalks.

Operation.	Northfield (Rice County).			Marshall (Lyon County).		
	Total acreage (three years).	Total cost.	Cost per acre.	Total acreage (three years).	Total cost.	Cost per acre.
Manuring	602.68	$868.08	$0.576	775.41	$1,140.48	$0.588
Seed value	509.35	108.68	.213	776.71	128.36	.165
Shelling seed	411.07	9.57	.023	467.37	13.06	.028
Plowing	605.89	730.28	1.205	579.78	602.50	1.039
Dragging	791.75	380.37	.480	681.97	305.12	.447
Planting (horse planter)	670.83	150.72	.225	711.08	180.27	.254
Cultivating	776.34	1,256.61	1.619	701.16	934.71	1.333
Weeding				133.04	14.57	.110
Husking on hill	331.32	1,164.77	3.516	169.21	440.09	2.601
Machinery cost			.413			.391
Land rental			3.500			3.000
Total			11.770			9.956

Cost of producing corn—cut, shocked, and shredded.

Operation.	Northfield (Rice County).		
	Total acreage (three years).	Total cost.	Cost per acre.
Manuring	602.68	$868.08	$0.576
Seed value	509.35	108.68	.213
Shelling seed	411.07	9.57	.023
Plowing	605.89	730.28	1.205
Dragging	791.75	380.37	.480
Planting (horse planter)	670.83	150.72	.225
Cultivating	776.34	1,256.61	1.619
Cutting (corn binder)	294.10	195.95	.666
Shocking and tying	270.28	142.24	.526
Twine	248.20	115.84	.467
Picking up ears	139.23	34.60	.249
Shredding	138.18	524.23	3.794
Machinery cost			1.202
Land rental			3.500
Total			14.745

[a] "Statistics of corn," Yearbook, U. S. Dept. Agr., 1907.

Cost of producing corn—cut, shocked, and hauled in from the field.

Operation.	Marshall (Lyon County).		
	Total acreage (three years).	Total cost.	Cost per acre.
Manuring	775.41	$1,140.48	$0.588
Seed value	776.71	128.36	.165
Shelling seed	467.37	13.06	.028
Plowing	579.78	602.50	1.039
Dragging	681.97	305.12	.447
Planting (horse planter)	711.08	180.27	.254
Cultivating	701.16	934.71	1.333
Cutting (corn binder)	194.09	128.22	.661
Shocking and tying	172.69	58.35	.338
Twine	218.90	80.18	.366
Hauling in			1.640
Machinery cost			1.161
Land rental			3.000
Total			11.020

These figures were based on 40 to 45 bushel yields in 1902, 1903, and 1904. There is not a great deal of difference in the tonnage of stalks between the 40-bushel crop and the 100-bushel crop, the difference being principally in the number and size of the ears. If the stalks are left on the ground, or if they are fed to stock and the manure returned to the ground, the only difference in fertilizer removal will be in the nitrogen, phosphoric acid, and potash in the grain. If the corn is fed and the manure returned to the ground, the loss of fertility would be a negligible quantity. The only other increased cost in caring for a large yield as compared with a small yield is in the case of hand husking and hauling of the product, a method now less followed than formerly, but one which the experiments above referred to indicate is more profitable than the cutting, binding, and shredding. It would not cost as much, however, to husk 100 bushels from 1 acre as from 2 acres, and it would not cost twice as much to husk 100 bushels from 1 acre as to husk 50 bushels from 1 acre, especially if the increased yield was due in part to larger-sized ears. If the harvesting is done by machinery, there would be practically no additional cost in harvesting a 100-bushel crop as compared with a 50-bushel crop. It is evident, therefore, that it would be highly profitable to reduce acreage and increase yield, and that the price could even be considerably reduced and a good profit made. As better and more careful methods of seed selection and culture come into vogue, it is possible that with the higher yields per acre thus secured the price of corn may fall considerably and still a larger profit might result in much the same way as the increase in the efficiency of labor-saving machinery.[a]

All of the investigations conducted by the Department of Agriculture and by the state experiment stations show clearly that where corn is continually cultivated on the same land the yield per acre is greatly reduced. Continued cultivation is especially destructive of

[a] See 13th Report of Commissioner of Labor, vol. 2, "Hand and machine labor;" also Yearbook, U. S. Dept. Agr., 1897, pp. 600-603.

humus and reduces the immediately available plant-food elements—nitrogen, phosphoric acid, and potash. The decaying organic matter resulting in the humus sets free in the soil the other elements of plant food from the only slightly soluble soil particles. It is, therefore, exceedingly important to maintain a sufficient amount of decaying organic matter in the soil to insure its best physical condition and the ready supply of plant food through its direct action.[a] As stated above, the first appreciable effect of this constant cropping is the lowering of the humus content of the soil, thus decreasing the nitrogen, and especially decreasing the power of the soil to absorb water and air. This brings about shallower rooting of the corn and makes it less resistant to fluctuations in moisture. The soil dries out more easily and during rains becomes too wet, excluding the air, bakes easily, and is more difficult to keep in tilth. The bacterial life of the soil is thus greatly reduced, resulting in the slower and imperfect decay of organic matter and the formation of nitrates, and a consequent reduction of the solution through bacterial and root action of the other elements of plant food in the soil. The earthworm fauna, which is so necessary to the proper development of humus and soil aeration, is also greatly reduced through the same causes, thus intensifying the unfavorable conditions. As these changes progress the bacterial and animal life changes and species become predominant that are unfavorable to the crops. The nitrifying and ammonifying bacteria become less active or are altogether suppressed, while the denitrifying and nitrite-forming species develop. The latter are well known to be injurious to plant roots. The earthworms die out and soon the life of the soil is gone. It becomes pasty and dead. Fungi often injurious to crops develop rapidly under these conditions, as in the case of the root-rot of Texas, which destroys several million acres of cotton each year. Crops growing in these pasty black adobe soils can not get enough air for the deeper roots, which, thus weakened, are attacked by the fungi present. Deep fall plowing, with a liberal use of barnyard and green manures, partially corrects the trouble and enables the plant to better resist the disease, but most of these soils, after they once get into this condition, also need, in addition to the cultural methods suggested, reinoculating with the natural flora and fauna of good fertile soils where active decay of organic matter by the right bacteria is taking place. These may be partly provided through manure, but it is often necessary to use either soil or cultures of the right forms.[b]

Constant cropping without rotation, even where there is no serious deterioration of the soil, may also cause the accumulation of insect, animal, and fungous pests of various kinds until it becomes impossible to grow the crop at all on such infected areas. The accumulations of nematodes and root insects are about the only injurious forms in the case of corn, but in the case of other crops, as will be discussed later, numerous other disease organisms cause serious trouble, as in the case of the cotton wilts, flax wilt, etc.

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[a] See Bul. 109, Minn. Agr. Exp. Sta.; Bul. 123, Ill. Agr. Exp Sta.; Farmers' Buls. 81 and 199, U. S. Dept. Agr.; and Soils, by Hilgard.

[b] See The present status of the nitrogen problem, Yearbook, U. S. Dept. Agr., 1906.

WHEAT.

The most careful investigations have indicated that wheat probably originated somewhere in the region of the Euphrates in extremely ancient times. From this region it gradually spread in all directions and is occasionally found in some of its various varieties in the earliest prehistoric remains of nearly all European, Asiatic, and North African countries. Its great value as food and the ease with which it can be carried from place to place, the facility with which it adjusts itself to changing conditions, have all resulted in the development of an immense number of varieties and strains. Even in the earliest prehistoric remains representatives of several distinct strains are found, indicating a very ancient culture.

For purposes of classification and description, eight fairly distinct groups, corresponding to eight botanical species, are recognized:

(1) Common bread wheat, *Triticum vulgare.*
(2) Club or square head, *T. compactum.*
(3) Poulard, *T. turgidum.*
(4) Durum, *T. durum.*
(5) Polish wheat, *T. polonicum.*
(6) Spelt, *T. spelta.*
(7) Emmer, *T. dicoccum.*
(8) Einkorn, *T. monococcum.*

While these large groups are generally considered as species, it must be understood that they probably originated from possibly one or two very closely related natural species, and the modifications resulting in the present rather distinct groups have been the result of long-continued culture and selection under different conditions. However, on account of the exceedingly long period of culture involved, the groups have become as well fixed as natural species.

As a food plant, wheat is even more important than Indian corn, and the demand for it is greater than that of any other cultivated crop. Many statistical studies have been made showing the relation between supply and consumption and the possible world production. It is evident that, with the increasing population of the wheat-using world under the conditions of modern life, there is some danger of the production falling below the demands for consumption. This matter has been discussed in great detail by Crookes.[a] In most of these studies, however, several important considerations have not been given due weight. The most important of these is the improvement in yield through the use of varieties carefully selected for high-yielding power for each locality where the crop is to be grown. This is particularly applicable to the wheat culture of the New World and Australia, where wheat is a more recent introduction and where in many cases it has not become fully acclimatized.

The second important factor is in the improvement of cultural methods, which is applicable throughout the world.

In 1899 Crookes[b] wrote: "The present acreage devoted to the world's growth of wheat is about 163,000,000 acres. At the average of 12.7 bushels per acre this gives 2,070,000,000 bushels. But thirty years hence the demand will be 3,260,000,000 bushels, and there will be difficulty in finding the necessary acreage on which to grow the

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[a] See The Wheat Problem, by Sir William Crookes. 1900.
[b] Loc. cit., p. 40.

additional amount required. By increasing the present yield per acre from 12.7 to 20 bushels we should, with our present acreage, secure a crop of the requisite amount." It is interesting to note, however, that for 1902 the production for the world reached 3,124,-422,000 bushels, the largest crop ever produced. This falls only a little short of Crookes's estimate of the requirements by the year 1930, and the total production of the world has not fallen below this point to date, being 3,189,813,000 in 1903, 3,152,127,000 bushels in 1904, 3,320,959,000 in 1905, 3,435,401,000 in 1906, and 3,108,526,000 in 1907. This increase is due in part to increased acreage and in part, though very slightly, to increased production per acre by the use of better methods. The following table[a] gives Crookes's estimates, based on the assumption that the population unit consumption and steady development would increase during the forty-three years beginning with 1899 as they had increased since 1871 up to the date of his forecast:

Date.	Bread eaters.	Food and seed required per unit (bushels).	Requiring bushels of wheat.	With yields averaging 12.7 bushels, acreage required.
1871	371,000,000	4.15	1,540,000,000	121,000,000
1881	416,000,000	4.38	1,822,000,000	143,000,000
1891	472,600,000	4.50	2,127,000,000	167,000,000
1898	516,500,000	4.50	2,324,000,000	183,000,000
1901	536,100,000	4.50	2,412,000,000	190,000,000
1911	603,700,000	4.50	2,717,000,000	214,000,000
1921	674,000,000	4.50	3,033,000,000	239,000,000
1931	746,100,000	4.50	3,357,000,000	264,000,000
1941	819,200,000	4.50	3,686,000,000	290,000,000

According to these figures the requirement in the year 1941 will be only 3,686,000,000 bushels, necessitating an acreage of 290,000.000 with an average yield of 12.7 bushels per acre, and feeding 819,200,000 bread eaters. Of course, these figures might be considerably modified at the present time, but they are perhaps as accurate forecasts as could be made of future requirements were the estimates to be projected beyond the present date as these were beyond the date on which they were figured.

The difficulty in all these figures is that there are immense areas in various parts of the world that are not considered at all adapted to wheat growth which can be made available when necessity demands. This is well illustrated by the Great Plains area west of the one hundredth meridian. This area, which at the time Crookes's figures were made was not considered available for wheat production, is now yielding over 50,000,000 bushels of one variety alone of the durum group, and improved methods of dry-land agriculture are making it possible to produce the hard winter wheats in the same area, so that it is exceedingly difficult even at the present time to estimate the potential wheat production of a strip of territory 300 miles wide exending from our northern border to the southern. On the basis of figures compiled by John Hyde, of the Bureau of Statistics, Department of Agriculture, included in full in Crookes's discussion of the wheat problem before referred to, the following statements are made:[b]

[a] Loc. cit., p. 244.

[b] Loc. cit., p. 195 et seq.

That the population of the United States in 1931, exclusive of colonial possessions or dependencies, will be at least 130,000,000 is as certain as any future event can be, but it is not nearly so easy a matter to forecast the agricultural production of that period. * * * What contribution, if any, will our farmers be able to make to the wheat supply of other countries when the time comes that provision has to be made for the varied requirements of a home population more than twice as large as that at the last federal census?

Those requirements will include a wheat crop of 700,000,000 bushels, without a bushel for export; an oat crop of 1,250,000,000 bushels; a maize crop of 3,450,000,000 bushels, and a hay crop of 100,000,000 tons, all for domestic consumption; with cotton and wool, fruits and vegetables, dairy and poultry products, meat, and innumerable minor commodities in corresponding proportions. The area necessary to the production of the three principal cereals alone will be over 15 per cent greater than the enormous total acreage devoted in 1898 to grain, cotton, and hay, while the mere addition of the two last-mentioned products and of the minor cereals will call for an acreage exceeding the total area of improved land in farms at the present time.

But what, it may be asked, is to prevent either (1) any necessary extension of the areas in farms, or (2) the bringing under cultivation of that large residue of unimproved land which amounted at the last federal census to no less than 42.5 per cent of the total farm area?

The great fact that underlies the enormous productive capacity of the United States to-day is, of course, the transfer from government ownership to individual proprietors, within a single generation, of a body of land hundreds of millions of acres in extent, and for the most part of extraordinary fertility. But, amazing as has been the increase in the farm area of the country during the last thirty years, it has not been sufficient even to keep pace with the growth of population. The addition of 128,300,000 acres, or 31.48 per cent, to the area in farms between 1870 and 1880 only increased the area per capita of population from 10.57 to 10.69 acres. By 1890 the area, notwithstanding a further addition of 87,100,000 acres, or 16.25 per cent, amounted to only 9.95 acres per capita, and the census of 1900 will almost certainly find it under 9 acres.[a]

That for general agricultural purposes the public domain is practically exhausted, and that, consequently, there can be no further considerable additions to the farm area of the country is too well-established a fact to be the subject of controversy. Of the entire area undisposed of, 72.7 per cent is in States wholly within the arid region, and all but a small part of the remainder is desert, mountain, or at best suitable only for grazing purposes. In Kansas, out of 1,061,000 acres undisposed of, only 116,000 acres are east of the one hundredth meridian, and these are described as broken and for the most part sandy. In Nebraska, 10,548,000 acres are still open to settlement, but not one acre in seven is in a region of sufficient rainfall for general agricultural purposes, and the best of the land is described by the General Land Office as fit only for grazing. In North Dakota the vacant land amounts to 20,575,000 acres, but on little more than one-tenth of this area could irrigation be dispensed with, even if the land were otherwise adapted to general farming. In Oklahoma, the youngest of the Territories, and the one containing the largest addition to the farm area of the country that has been made within many years, of the 7,007,000 acres of government land still vacant, 3,250,000 acres lie between the ninety-ninth and one hundredth meridians and a like amount, making altogether 93 per cent of the whole, west of the one hundredth.[b] The vacant land in the Pacific States amounts to 91,843,000 acres; but of the 42,503,000 acres in California, 19,000,000 acres are "barren, irreclaimable wastes," 19,875,000 acres "desert and grazing," and 3,628,000 acres "woodland and forest;" the 35,898,000 acres in Oregon include 17,067,000 acres of "desert and grazing," and 18,831,000 acres of "woodland and forest," while the 13,443,000 acres in Washington comprise 3,847,000 acres of "desert and grazing," and 9,596,000 acres of "woodland and forest."

It should not be forgotten in this connection that it is no longer the policy of the American people or of its representatives in Congress to permit the con-

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[a] The census for 1900 shows the per capita acreage to be a little over 11 acres.

[b] As previously stated, a large proportion of this land west of the one hundredth meridian is now believed to be available for dry-land agriculture and is already contributing over 50,000,000 bushels of one variety of wheat alone to the supply of the United States, over 20,000,000 bushels of which have gone into the export trade.

tinued destruction of the national forests without regard to the needs of the future. It should also be borne in mind that, according to the United States Geological Survey, the entire water supply of the Pacific States available for irrigation is only sufficient for some 23,000,000 additional acres, or about 1 acre in 4 of the unappropriated public lands in those States. In the entire arid region the available water supply, as similarly estimated by the United States Geological Survey, is only sufficient for the irrigation of 71,500,000 additional acres, or 1 acre in 7½ of the area undisposed of. * * *

The extent to which the total farm area of the country can be increased by the reclamation of desert lands will therefore be seen to be very small, if not absolutely insignificant; indeed, it is a question whether it will be sufficient even to counterbalance those constant encroachments upon the productive area which arises from the growth of cities, the building of railroads, and the general development of commerce and nonagricultural industry.

Mr. Hyde then goes on to discuss the great body of unimproved farm land. In the census of 1890, which he had under consideration, there were about 115,000,000 acres of unimproved land in the various farms of the different regions of the United States. The distribution of this land is very ununiform and the extent to which it may be made available is found to differ widely. In Illinois and Iowa it is estimated to be between 15 and 20 per cent of the total farm area; in New York, New Jersey, Pennsylvania, Delaware, Ohio, Indiana, Kansas, and Nebraska, between 20 and 30 per cent; in Vermont, Connecticut, Maryland, Michigan, Missouri, North Dakota, and South Dakota, between 30 and 40 per cent; in Massachusetts, Rhode Island, Kentucky, Wisconsin, and Minnesota, between 40 and 50 per cent; and in Maine, New Hampshire, Virginia, and West Virginia, between 50 and 60 per cent.

Assuming [says Mr. Hyde][a] that the entire region will, under the influence of high prices, have 85 per cent of its total farm area brought under cultivation within the next thirty years, there will be added to the productive area in this region 60,000,000 acres, with state and railroad lands to the possible extent of 20,000,000 acres in addition. This will fall so far short of the requirements of our own population that it is necessary to seek other possible additions to the cultivable area.

Not for the purpose of growing wheat, but under the influence of those generally higher prices which any considerable and long-continued increase in the price of wheat would bring about by reducing the acreage in other products, the South might conceivably add to her productive area as much as 30,000,000 acres. Ten million acres might be added on the Pacific coast and 3,000,000 acres in the arid region. This would make the gross addition 123,000,000 acres, against which must be set those continual withdrawals of land from agricultural uses which not even a high degree of agricultural prosperity would entirely prevent. Assuming the annual rate of diversion to be diminished by one-half, the loss during the next thirty years would amount to about 15,000,000 acres, making the net increase 108,000,000 acres.

This will constitute an enormous addition to the productive capacity of the farms of the country, and one, the contemplation of which, aside from the question of consumption, might well appal our much-discouraged farmers. Considered, however, in the light of the requirements of a population of 130,000,000 the figures assume an entirely different aspect. On the basis of our present actual consumption as a people, to the entire exclusion of our export trade, the country will require by the year 1931 the following additional acreage: For wheat, 13,500,000 acres; for maize, 66,000,000 acres; for oats, 23,700,000 acres; for the minor cereals, 10,000,000 acres, and for hay, 40,500,000 acres, a total of 153,700,000 acres, without making any provision for the proportionately increased consumption of vegetables, fruits, and other products. Instead, therefore, of the probably largely increased acreage, bringing down prices, or proving unprofitable to the farmers, there will be a deficiency of at least 50,000,000 acres. Indeed, it will be more than this, since it can not be supposed for a moment that the unimproved lands left to the last are anything like equal in

[a] The Wheat Problem, p. 219 et seq.

natural fertility to those first selected for cultivation. On the other side of the account, however, we have to place whatever increase in yield per acre may be brought about by improved methods of farming. But whatever agricultural science may be able to do in this direction within the next thirty years, up to the present time it has only succeeded in arresting that decline in the rate of production with which we have been continually threatened. * * *

It must be borne in mind that it is only to a very small extent indeed that scientific methods have as yet been employed in the growing of field crops. It is unquestionably to the laboratory that we shall have to look for relief, except in so far as it may be afforded by the Government's undertaking the construction of storage reservoirs in the arid region that might reclaim not to exceed 71,500,000 acres, less whatever small area might in the meantime have been brought under cultivation in that region through private enterprise. * * *

The cultivation of wheat at the expense of other necessary crops will, however, be held in check by two very powerful influences. The first will arise from the fact that a reduction of the acreage under any product of general use below the actual requirements of the country will instantly—perhaps even prospectively—affect the price of that product, possibly in a proportion even greater than that by which its acreage is diminished, and may even be sufficient to constitute it a competitor with wheat on equal terms for the farmer's favor. The second check will be found in the fact that the American farmer, north, south, east, and west, has at last fully awakened to the safety, stability, and, in the long run, increased profit resulting from a judiciously diversified system of farming. The one-crop system has passed away, never to return, and before wheat can be extensively cultivated at the expense of other products it will not only have to command what would appear to us as an excessively high price, and afford a reasonable assurance of its continuing to do so, but would have to do this without affecting to any considerable extent the price of other products.

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To discuss the extent to which under conceivable conditions the United States may, notwithstanding this somewhat dubious outlook, still continue to contribute to the food supply of other nations, would be little more than speculation. It is sufficient for the writer's present purpose to have called attention to the enormous prospective increase in the requirements of our own population, and to some of the changes in the agricultural situation which such increase will involve.

This discussion of the subject is quite in accord with the general view taken by Mr. Crookes and a number of others who have forecasted the situation, but the difficulty of making reliable estimates of food production and acreage is too apparent to need further discussion. The same is true regarding the acreage and production of foreign countries, some of which, even in the original home of the wheat plant, are producing only about 9 bushels per acre on the average, as indicated in the following table:[a]

Average yield of wheat per acre in—	Bushels.
Denmark	41.8
United Kingdom	29.1
New Zealand	25.5
Norway	25.1
Germany	23.2
Belgium	21.5
Holland	21.5
France	19.4
Hungary	18.6
Roumania	13.5
Austria	16.3
Poland	16.2
Canada	15.5
Argentina	13.0
Italy	12.1
United States (mean)	12.0

[a] The Wheat Problem, p. 244.

Average yield of wheat per acre in—	Bushels.
India	9.2
Russia in Europe	8.6
Algeria	7.5
South Australia	7.0
Australasia	6.8

The average acreage devoted to wheat in the United States from 1866 to 1907 has gradually increased, slightly fluctuating from year to year through various causes, especially the price of wheat, the price of competing crops, etc. At the close of the civil war, in 1866, there were 15,424,496 acres devoted to wheat, with an average yield of 9.9 bushels and an average farm price of a little over $1.52 per bushel, 12,646,941 bushels of this crop being exported. In 1880 the acreage had increased to 37,986,717, with an average yield of 13.1 bushels and a farm price of a little over 95 cents, 186,321,514 bushels being exported.[a] Up to 1901 the average fluctuated a little above and a little below the 37,000,000-acre point, reaching in 1901 49,895,514 acres, with an average yield of 15 bushels and an average farm price of 62.4 cents, with an export of 234,772,516 bushels. In 1902 the acreage dropped off something over 3,000,000 acres, and in 1903 it came back again to 49,464,967 acres, with an average yield of 12.9 bushels and an average farm price of 69.5 cents, and with an export of 120,727,613 bushels. In 1904, 1905, 1906, and 1907 the acreage has been between 44,000,000 and 47,000,000, with an average yield ranging between 12.9 and 15.5 bushels and a farm price ranging between 66 and 92 cents, the high prices running up as high as $1.13 in the year 1904 and $1.06 in 1906. The exports since 1903 have fallen off considerably. In 1903 the export was 120,727,613 bushels and in 1904 it was 44,112,810. This was coincident with the rust epidemic. In 1905 the exports amounted to 97,609,007 bushels; in 1906, 146,700,425 bushels; and for 1907 the figures were 163,043,669.[a] There is no positive evidence, therefore, from the figures available of any falling off in the ability of our farmers to meet the demand for home consumption of wheat and still supply a large amount for export.

I have already referred incidentally to the difficulty of determining the potential wheat-producing power of the land not now in farms, and of the uncultivated area in farms. As a further illustration of the difficulty of determining this, it is simply necessary to point out that most investigators, including Crookes and Hyde, up to ten years ago, figured that the area west of the one hundredth meridian was practically available only for grazing, with the exception of only a small per cent available for irrigation. Probably not more than 5, or at the most 10, per cent of the arable land west of the one hundredth meridian is considered available for irrigation, owing to the scarcity of water. Even this, however, is based upon the present wasteful methods of using water, and is subject to considerable revision when conditions of farming are such as to warrant subirrigation methods, which are now used in many localities with a saving of over 50 per cent of water. The irrigation ditches are now most of them not cemented or properly silted, so that there is a great waste by seepage. The water, furthermore, is exposed to evaporation,

[a] Figures of Bureau Statistics, U. S. Dept. Agr.; subject to slight change by Dept. Com. and Lab.

by which large quantities are lost. There are many methods that might be practically devised for using water more economically than at present, but, leaving the question of irrigated agriculture aside, the Great Plains area, which has not been considered as a potential feature in wheat production, is a territory over 300 miles wide and 1,000 miles long, and, on a most conservative estimate, contains 50 per cent of land which could be devoted to wheat culture, and, as a result of careful tests made by the Department of Agriculture, state experiment stations, and practical farmers it has been shown that, by the use of drought-resistant varieties of wheat and by the employment of cultural methods which conserve the natural rainfall, at least 96,000,000 acres of this land could be made to produce an average yield of 15 bushels per acre annually under the ordinary methods of culture now practiced by the best farmers of that region.

The possibilities of increasing the wheat yield in the present well-established wheat areas have hardly been considered. As will be shown later, a very large number of varieties are now grown, many of them not well adapted to the conditions of soil and climate under which they are cultivated. An average increased yield of 5 bushels to the acre could be secured simply by putting into the hands of the farmers better adapted strains for their particular conditions. This is now rapidly taking place.

A study of the statistics of yield for the different wheat areas of the United States shows a gradual upward tendency for the United States as a whole for ten-year periods. Representing the average yield of the forty years from 1867 to 1906 by 100, the relative average yield per acre in each decade was as follows: 1867–1876, 94; 1877–1886, 98; 1887–1896, 100; 1897–1906, 108. The actual yields for States and periods are shown in the table of ten-year average yields, herewith appended.

According to investigations made by this department and published in Bulletin No. 24 of the Division of Vegetable Physiology and Pathology, "The Basis for the Improvement of American Wheats," 1900, as a foundation for rational wheat improvement, a knowledge is required, first, of the characteristics and needs of different wheat districts, and, second, of the characteristic qualities of the natural groups of wheat. On the basis of conditions of soil and climate and the nature of the varieties adapted to these conditions, the United States may be considered to be divided into eight wheat districts, as follows: (1) Soft wheat district, including mainly the Middle and New England States; (2) the semihard winter wheat district, including Ohio, Indiana, Illinois, Michigan, and a small part of Wisconsin; (3) the southern wheat district, including approximately the Southern States; (4) the hard spring wheat district, covering the northern portion of the States of the plains; (5) the hard winter wheat district, covering the central portion of the States of the plains; (6) the durum wheat district, covering the western portion of the States of the plains; (7) the irrigated wheat district, including approximately the Rocky Mountain and Basin States; and (8) the white wheat district, including the Pacific Coast States.

Certain general needs, such as early maturity, greater yielding power, and better adapted varieties, are common to all these districts and must be kept constantly in mind in connection with all efforts made to improve varieties. Other characteristics and needs are more special and are stated herewith under headings of the different districts:

Soft wheat district:
(*a*) Present average yield per acre, about 14⅗ bushels.
(*b*) Chief varieties now grown: Fultz, Fulcaster, Early Genesee Giant, Mediterranean, Early Red Clawson, Longberry, Jones's Winter Fife, Red Wonder, Gold Coin, Bluestem, Dietz, Red Cross.
(*c*) Needs of the grower: Harder-grained, more glutinous varieties; hardier winter varieties for the most northern portions; early maturity; rust resistance.

Semihard winter wheat district:
(*a*) Present average yield per acre, about 14 bushels.
(*b*) Chief varieties now grown: Fultz, Poole, Rudy, Valley, Nigger, Dawson's Golden Chaff, Early Red Clawson.
(*c*) Needs of the grower: Hardness of grain; rust resistance; hardy winter varieties.

Southern wheat district:
(*a*) Present average yield per acre, about 9⅗ busbels.
(*b*) Chief varieties at present grown: Fultz, Fulcaster, Red May, Rice, Everett's High Grade, Boughton, Currell's Prolific, Purple Straw.
(*c*) Needs of the grower: Rust resistance; early maturity; resistance to late spring frosts; stiffness of straw.

Hard spring wheat district:
(*a*) Present average yield per acre, about 14 bushels.
(*b*) Chief varieties at present grown: Scotch Fife, Bluestem, Wellman's Fife, Velvet Chaff Spring.
(*c*) Needs of the grower: Early maturity; rust resistance, drought resistance; hardy winter varieties.

Hard winter wheat district:
(*a*) Present average yield per acre, about 14 bushels.
(*b*) Chief varieties at present grown: Turkey, Fulcaster, Kharkof, Zimmerman, Fultz.
(*c*) Needs of the grower: Drought resistance; early maturity.

Durum wheat district:
(*a*) Present average yield per acre, 11½ bushels.
(*b*) Chief varieties at present grown: Mediterranean, Nicaragua, Fulcaster, Turkey, Kubanka (in north).
(*c*) Needs of the grower: Durum varieties for southern district; drought resistance; rust resistance; early maturity.

Irrigated wheat district:
(*a*) Present average yield per acre, about 21 bushels.
(*b*) Chief varieties at present grown: Sonora, Taos, Turkey, Little Club, Defiance, Kharkof, Kubanka.
(*c*) Needs of the grower: Increase of the gluten content; early maturity.

White wheat district:
(*a*) Present average yield per acre, about 15 bushels.
(*b*) Chief varieties at present grown: Australian, California Club, Sonora, White Winter, Foise, Palouse Bluestem, Palouse Red Chaff, Oregon Red Chaff, Little Club.
(*c*) Needs of the grower: Early maturity; nonshattering varieties; hardy winter varieties in the colder portions.

Attention has already been called to the eight principal groups of our cultivated wheats. The special characteristics of these groups of wheats that are of prime importance in the work of wheat breeding are here given:[a]

1. Common bread wheat group:
(*a*) Excellence of gluten content for bread making.
(*b*) Excellence of certain varieties for cracker making.
(*c*) Yielding power of certain sorts.
(*d*) Rust resistance (in some varieties).
(*e*) Winter hardiness of certain varieties.
(*f*) Resistance to drought of certain varieties.
(*g*) Early maturity (in some varieties).

[a] Bull. No. 24, Div. Veg. Phys. and Path., U. S. Dept. Agr., 1900, pp. 79–83.

2. Club or square-head group:
   (a) Great yielding power.
   (b) Stiffness of straw.
   (c) Freedom from shattering.
   (d) Early maturity (in some varieties).
   (e) Drought resistance (in some varieties).
   (f) Excellence of certain sorts for making crackers and breakfast foods.
3. Poulard group:
   (a) Excellence of certain varieties for making macaroni.
   (b) Resistance to orange leaf-rust.
   (c) Resistance to drought.
   (d) Stiffness of straw.
4. Durum group:
   (a) Excellence of gluten content for making macaroni and other pastes.
   (b) Resistance to drought.
   (c) Resistance to orange leaf-rust.
5. Polish wheat group:
   (a) Quality of gluten content for making macaroni.
   (b) Resistance to drought.
   (c) Resistauce to orange leaf-rust.
6. Spelt group:
   Desirable qualities—
      (a) Ability to hold the grain in the head.
      (b) Constancy in fertility.
      (c) Hardiness of certaiu winter sorts.
   Undesirable qualities—
      (d) Brittleness of the head.
      (e) Rust liability.
7. Emmer group:
   Desirable qualities—
      (a) Ability to hold the grain in the head.
      (b) Drought resistance.
      (c) Resistance to orange leaf-rust.
   Undesirable qualities—
      (d) Brittleness of the head.
      (e) Adaptability ouly for spring sowing, as a rule.
8. Einkorn group:
   Desirable qualities—
      (a) Ability to hold the grain in the head.
      (b) Resistance to orange leaf-rust.
      (c) Hardiness.
      (d) Resistance to drought.
      (e) Stiffness of straw.
   Undesirable quality—
      (f) Brittleness of the head.

Wheats may also be grouped geographically. On this basis groups of varieties having certain special qualities are located approximately as follows:

(a) Starchy white wheats: Pacific Coast and Rocky Mountain States, Chile, Turkestan, Australia, and India.
(b) Amber or reddish grained wheats, also starchy: Eastern States, western and northern Europe, India, Japan, and Australia.
(c) Excellence of gluten content for making the best bread: Northern and Central States of the Plains, Canada, eastern and southern Russia, Hungary, Roumania, and southern Argentina.
(d) Resistance to orange leaf rust: Southern Russia, Mediterranean and Black Sea regions, and Australia.
(e) Excellence of gluten content for making macaroni: Southern Russia, Algeria, and the Mediterranean region in general.
(f) Stiffness of straw preventing lodging: Pacific Coast States, Japan, Turkestan, Mediterranean region, and Australia.
(g) Yielding power (at least in proportion to size of head): Pacific Coast States, Chile, and Turkestan.
(h) Nonshattering varieties: Pacific Coast States, Chile, Turkestan, Germany (spelts), and East Russia (emmers).
(i) Constancy in fertility: Germany (spelts) and southern Europe.
(j) Early maturity: Japan, Australia, and India.
(k) Resistance to drought and heat: East and South Russia, Kirghiz steppes, Turkestan, and southern Mediterranean region.

(*l*) Resistance to drought and cold: East Russia.

Of the many wheat introductions made into this country in the past, the following are among those of the greatest moment, and which have completely revolutionized the wheat industry in places:

(*a*) Mediterranean, introduced first in 1819.
(*b*) Fife wheats, introduced first into Canada and then into the northern States of the Plains.
(*c*) Turkey wheat, first introduced into Kansas about twenty-five years ago from Taurida, in Russia.
(*d*) The California Club, Australian, and Sonora, introduced into the Pacific Coast States.

Field experiments of the department have shown that in the common bread-wheat group there is a very close constant relation between the autumn condition of the young plant on the one hand and winter hardiness and quality of grain on the other.

Wheat is very susceptible to changes of environment, but especially in regard to color, hardiness, and chemical composition of the grain.

In general, regions possessing black prairie soils and characterized by violent climatic extremes, especially extremes of heat and drought, produce wheats that are hardiest, have the hardest grains, and are the best in quantity and quality of gluten content.

Considering all qualities, the best wheats of the world are of Russian origin, coming particularly from eastern and southern Russia, the Kirghiz steppes, and Turkestan. Of Russian varieties so far known, the following are among the best, if not the very best:

Arnautka, Ghirka Spring, Crimean, Mennonite, Yx, Kubanka, Ghirka Winter, Buivola, Kubanka Red Winter, Chernokoloska, Turkey, Russian, Sarui-bug-dai, Beloturka.

The earliest ripening wheats are often dwarfed. The following varieties are among the best of this class:

Yemide, Onigara, Shiro-Yemidashi, Kintama, Kathia, Roseworthy, Early Baart, Early Japanese, Japanese No. 2, Nashi, Allora Spring, Steinwedel, King's Jubilee.

The following varieties are among the best known of the durum and poulard groups:

Arnautka, Kubanka, Beloturka, Chernokoloska, Medeah, Sarui-bug-dai, Cretan, Galland's Hybrid, El Safra, Petanielle noire de Nice, Volo, Missogen, Atalanti, Nicaragua.

Common bread wheats can not be depended upon to resist rust, but the best in this regard are probably the following:

Turkey, Pringle's Defiance, Rieti, Pringle's No. 5, Nashi, Saskatchewan Fife, Theiss, Bellevue Talavera, Arnold's Hybrid, Crimean, Oregon Club, Odessa, Velvet Bluestem, Sonora, Prolifero, Mediterranean, Deitz Longberry, and Mennonite.

Einkorns resist leaf-rust completely, and emmers resist it to a high degree.

Some of the very hardiest winter varieties so far tried in this country are:

Turkey, Yx, Crimean, Ghirka Winter, Bearded Winter.

Club wheats are usually soft-grained and tender sorts, adapted only to mild climates like that of California. Among the best of this group are:

Little Club, California Club, Herisson barbu, Palouse Red Chaff, Chili Club, Sicilian Red Square-head, Herisson sans barbes.

Some of the most popular and valuable wheats of our country have been produced by simple selection, though in some cases the indications are strong that they were originally the result of natural crossing. The best known of such varieties are:

Flutz, Clawson, Gold Coin, Rudy, Wellman's Fife, Currell's Prolific.

Selection plays far the most important part in wheat breeding, and necessitates on the part of the experimenter a thorough knowledge of varieties and their relations to each other and to their environment.

Simple selection of individuals, however, for the improvement of the same variety, can and should be practiced on every farm. Very little extra time or trouble is required, but the gain is great.

Among the most valuable wheats of the United States that have been produced through hybridization are the following:

Fulcaster, Gypsum, Improved Fife, Quartz, Ruby, Jones's Winter Fife, Early Genesee Giant, Early Arcadian, Pringle's Defiance, Pringle's No. 5, Hornblende, Felspar, Blount's No. 10, Diamond Grit, Early Red Clawson, Early White Leader.

For the most complete success in wheat improvement through hybridization it is necessary to practice composite crossing with parents selected from widely different wheat groups.

The wheat plant is so closely self-fertilized in nature that the practice of composite crossing produces some most interesting and remarkable results. There is apparently no end to the variations exhibited by the sporting progeny in such cases, and, accompanied by discriminating selection, the possibilities of wheat improvement in this way are practically unlimited.

Studying along the lines here laid down, the Department of Agriculture and a number of the state experiment stations have made great progress in improving the varieties of wheat cultivated in these various regions. It has been possible to secure acclimatized strains in various parts of the Old World wheat areas where, as the result of centuries of culture under severe limiting conditions, strains and varieties have been gradually developed through natural and artificial selection very resistant to those conditions. Thus we find very cold and drought resistant durums, like the Kubanka and Arnautka, adapted to the cold dry northern area and other strains developed in northern Africa and the Mediterranean region adapted to the hot dry situations of Texas and Oklahoma. The hard winter wheats of the Great Plains and the Mississippi Valley are inferior in cold-resisting power and yielding power to very closely related strains which have been secured in Russia. As a result of careful explorations of European Russia, including the Caucasus and a portion of the Kirghiz Steppes, as well as Hungary, Roumania, and other portions of Europe, a very large number of promising strains of different varieties were secured, which were tested in connection with a large number of strains secured in this country, making altogether about 1,000 varieties.

The Kharkof strain of the so-called Turkey wheat has carried the range of winter wheat culture from southern Nebraska into southern North Dakota, a distance something over 400 miles, and has carried the western range of winter wheat culture beyond the one-hundredth meridian. This strain is also proving valuable in Iowa, Minnesota, Wisconsin, and Illinois. The winter wheats, besides being more certain in yield, average about 5 bushels more than spring wheats.

The rust-resisting qualities of some of the durum wheats have been bred into the Bluestem strains, making them very much more valuable for culture in the northern Mississippi Valley, but these have not yet been distributed by the department.

The great problem in the South is good varieties of wheat, better adapted for growth under the warmer conditions, and which are rust-resistant. While very little has yet been done along this line, it is undoubtedly possible by the introduction of strains adapted to southern conditions and having greater rust resistance to very greatly increase the now very low yield of the Southern States. Several investigators have from time to time pointed out that the highest yield of any strain of a crop is usually produced near the northern limit of its production. This is true so far as any given strain or variety is concerned, but there is no reason why the Southern States should not be the northern limit of production for certain varieties of wheat, the same as northern Canada is the limit for other varieties. This point has been overlooked in much of the discussion upon the potential wheat-producing power of the Southern States. It is the opinion of those who have given this question long and careful study that the average wheat production of the United States as a whole could easily be doubled by the use of better varieties and better cultural methods. How rapidly changes of this kind will take place will depend upon how rapidly information can be diffused among the farmers. If dependence is placed upon the distribution of information through publications, the change will be very slow, but if the information is carried to the people directly, as is being done by the Department of Agriculture in its farm demonstration in the South, it is believed that even a few years will suffice to get the people to use better methods. It will then be simply a question of how rapidly the scientists can improve the strains and get them into condition for distribution and general use.

The first steps must necessarily be those more fundamental features of general farm practice—the diversification of crops, building up of the humus of the soil by the use of barnyard manure and green crops turned under, more attention given to the selection of even ordinary varieties of seed, etc. As soon as the farmer makes the first steps in this direction, he is able to appreciate and make better use of more highly selected strains and more complicated methods.

The breeding work is actively in progress by many of the state stations, as well as the department experts, and it is probable that the progress of the breeder will fully keep pace with the development of the farmer and that the United States can be depended upon, not only to feed its own rapidly increasing population, with the same relative proportion of wheat that they now use, but that it will have a large and ever increasing quantity for export.

So far as the effect of soil conditions on wheat yield is concerned, it has been proved beyond question that, where wheat is grown continuously on the same soil without the addition of organic matter, the productive power of the soil is reduced. It has been shown beyond any question that the continuous growth of cultivated crops is even more destructive of soil humus than the continuous growth of grain crops. The stirring of the soil in the process of cultivation stimulates the action of the nitrifying and ammonifying bacteria, which convert the organic nitrogen of the soil into available form, so that it is either taken out by the crops or is leached away.

The influence of the different systems of farming on the chemical and physical properties of the soil is well illustrated by the following facts secured at the Minnesota Experiment Station, and which are typical of the results secured by practically all other investigators in this field:[a]

Influence of different systems of farming on the chemical and physical properties of soils.

Character of soil.	Weight per cubic foot.	Humus.	Nitrogen.	Phosphoric acid combined with humus.	Water-holding capacity.
	Pounds.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1. Cultivated 35 years; rotation of crops and manure; high state of productiveness	70	3.32	0.30	0.04	48
2. Originally same as 1; continuous grain cropping for 35 years; low state of productiveness	72	1.80	.16	.01	39
3. Cultivated 42 years; systematic rotation and manure; good state of productiveness	70	3.46	.26	.03	59
4. Originally same as 3; cultivated 35 years; no systematic rotation or manure; medium state of productiveness	67	2.45	.21	.03	57

[a] Humus in Its Relation to Soil Fertility, by Harry Snyder, Yearbook, U. S. Dept. Agr., 1895, p. 141.

Soils Nos. 1 and 2 are from two adjoining farms, and originally had practically the same crop-producing power. No. 1 has received regular and liberal dressings of manure, and has produced wheat, corn, oats, timothy, and clover in rotation. There has been no apparent decline in fertility. No. 2 has been under continuous grain cultivation and has never received any farm manure or other humus-forming materials. During the first few years heavy crops of wheat were raised, but during the past few years the yield has been very low, especially in dry seasons. The land has been reduced in wheat-producing power from 25 to 8 bushels per acre.

The main difference between the two soils at the present time is in the amount of humus and nitrogen and phosphoric acid.

Soils Nos. 3 and 4 are from the same farm. No. 3 has been cropped forty-two years, timothy and clover, wheat, oats, and corn having been raised in rotation. Every five years the land has received 10 tons of stable manure per acre. No. 4 has been cropped only thirty-five years, producing mainly wheat, oats, and corn, with an occasional crop of timothy. It has not been cropped continuously to one crop, neither has it been under a regular system of rotation. The soil which has been cropped forty-two years shows more humus and nitrogen than the one which has been cropped thirty-five years.

The earlier results secured in these experiments in Minnesota have been confirmed by all of the later investigations. In Bulletin No. 109 of the Minnesota Experiment Station, issued in June, 1908, pages 330 to 334, the results are summarized as follows:

1. Continued cropping of soils to grains only, without any system of rotation, or other treatment, is telling severely upon the original stock of half-decomposed animal and vegetable matter and nitrogen. Soils which have produced grain crops exclusively for ten or fifteen years contain less humus and nitrogen than adjoining soils that have never been plowed.

2. Soils which have been cropped until the organic matter and humus have been materially decreased retain less water and dry out more readily than when there is a larger amount of organic matter present in the soil.

3. Soils which are rich in humus contain a larger amount of phosphates associted with them in available forms than soils that are poor in humus.

4. Soils which are rich in humus and organic matter produce a larger amount of carbon dioxide which acts as a solvent upon the soil particles and aids the roots in procuring food.

5. One-half of a sandy knoll, heavily manured with well-rotted manure, contained nearly a quarter more water during a six weeks' drought than the other half that received no manure.

6. The supply of organic matter in the soil must be maintained, because it takes such an important part, indirectly, in keeping up the fertility. A good system of rotation, including sod crops and well-prepared farm manures, will do this, and will avoid the introduction and use of commercial fertilizers which are now costing the farmers of the United States over $80,000,000 annually. It will not do to wait until this question forces itself upon us.

7. A rotation of crops will soon be necessary on account of the peculiar composition of some of the soils and corresponding subsoils, especially those where the surface soils are richer in phosphates and nitrogen while the subsoils are richer in potash and lime. By means of rotation the full benefit of the strong points of both the top soil and the subsoil will be secured.

The decay of the humus and liberation of its nitrogen is only one of many changes that has taken place. Loss of the element nitrogen can not be said to be the only cause of decline in fertility, as field experiments with fertilizers on old grain lands show that nitrogen alone, when added to the soil, fails to entirely restore the fertility. In addition to the decay of the humus and loss of nitrogen, the mineral elements of plant food have undergone changes in combination, the soils have become lighter in color and otherwise modified in physical properties. * * *

Commercial fertilizers should not be used indiscriminately on old soils with a view of securing large yields, and it is not feasible by their use alone to economically restore the fertility to soils that have been impoverished by exclusive cropping to small grains. Commercial fertilizers are of great value when judiciously employed in a rotation and for encouraging the growth of legumes, as clover, so as to add nitrogen to the soil from atmospheric sources. * * * Commercial fertilizers can not take the place of farm manures or crop residues, particularly those from clover and timothy, for permanently improving the soil, but they aid in the production of some crops and often assist a crop, as clover, which in turn is beneficial in adding nitrogen and humus to the soil.

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A rotation of grain crops alone, without the production of clover or a grass crop, was found not to be sufficient to conserve the nitrogen content of the soil, even where farm manures were used. A rotation of crops, in order to be effectual, must contain clover as one of the essential parts.

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The beneficial action of a clover sod, grass crop residues, and farm manures upon the soil is not alone confined to supplying nitrogen and humus-forming materials, but chemical, bacteriological, and physical changes are also promoted in the soil. * * *

The indiscriminate practice of bare summer fallowing has been another cause of loss of the soil's nitrogen and humus. * * * Experiments show that when summer fallowing is practiced five times more nitrogen is rendered soluble and available than is required for the succeeding crop; and the soluble nitrogen that is not utilized as plant food is readily lost. * * *

On most western farms it is more economical at the present time to make the reserve mineral matter available as plant food than to purchase new stores. In many soils there is a large amount which is not in the most available forms, but is capable of being made so by cultivation.

As a general result of the cropping system it was found that any system which provided for the maintenance of a supply of vegetable matter in the soil, either by manuring or by the growing of pasture or meadow crops, has given profitable returns. A standard five-year rotation—first year, corn, receiving 8 tons of manure per acre; second year, wheat; third and fourth years, meadow; fifth year, oats—has given an average gross income per year for the State of Minnesota, based on average farm prices, of $14.08. The cost of production, including $3.50 land rental, is $9.05, leaving the net annual income $5.03 per acre.

The plots which have grown cultivated crops, such as corn, potatoes, and mangels, continuously without manure, have given poorer returns than have the plots which have grown grain continuously without manure.

A four-year rotation—millet, barley, corn, and oats—gave no better returns than did the plot on which wheat was grown continuously.

The yields of wheat in the standard five-year rotations have ranged between 20 and 30 bushels, some seasons and rotations giving as high as 35 bushels, while the average for the State is about 13 bushels.

Emmer.—Before closing the discussion of wheats attention should be called to emmer, which is destined to be an exceedingly important dry-land crop for high altitudes and poor soils. The following is abstracted from Farmers' Bulletin 139:

Emmer is a species of wheat, *Triticum dicoccum*, probably derived in prehistoric times in southeastern Europe from a still simpler species, *T. monococcum*. It is often confused with another similar species, *T. spelta*, and is thus incorrectly called "spelt." The grain is somewhat similar to that of spelt, but is usually harder, more compressed at the sides, and redder. Emmer is a much more hardy plant than spelt in every way. It resists drought and attacks of leaf rust to a great degree. Fall-sown varieties are also quite winter-hardy. It will produce a fair crop under almost any condition of soil and climate, but thrives best in a dry prairie region with hot summers, where it gives excellent yields, 30–60 bushels. The grain is largely cultivated in the upper Volga region of Russia, where the climatic conditions are more severe than in our northern Great Plains region. Excellent varieties are also grown in the North Caucasus, in Germany, Switzerland, France, Italy, Servia, Abyssinia, northern India, China, and Thibet. Only a few varieties, however, have yet been introduced and tested in this country. From the tests thus far made the Russian white-chaff varieties give excellent results in the northern plains district, and the black winter varieties give good results further South. With the introduction and acclimatization of new varieties this grain promises to take an important place in our agriculture, replacing oats and barley under conditions too severe for those crops and being about equal to them as stock food.

OATS.

A statement [a] of the status of oat culture in the United States has been especially prepared by Mr. C. W. Warburton and is submitted herewith.

The improvement and adaptation of varieties and the greatly increased yields resulting from such work are fully as great as in the case of corn and wheat.

Although oats exceed in nutrition value our other cereals, probably less care has been given to their culture than to any other important crop; oats are usually grown also on the poorest land. Their great value as feed, especially for horses, results in their culture even at a loss, so far as their market value is concerned. The acreage devoted to oats doubled from 1879 to 1887 and increased from 1887 to 1900 from 25,920,906 acres to over 27,000,000, with a corresponding increase in yield. In 1907 the acreage was 31,837,000, but on account of rust, smut, insect pests, and unfavorable weather conditions, the yield fluctuated considerably in various years and localities. The loss from smut alone is estimated at not less than 4 per cent of the crop, or on an average of about 34,000,000 bushels. This can be easily prevented at very small cost. Rust is more difficult to control, except through the use of resistant varieties. The loss caused is fully as great as that caused by smut. Selection and adaptation of varieties, with better rotation systems, will greatly increase the yield per acre as soon as there is demand for it. At current prices the acreage will probably remain about as at present, with a tendency to decrease as average yields increase as the result of better systems of rotation. The net profits will at the same time considerably increase.

BARLEY.

Barley is successfuly cultivated under a wider range of climatic and soil conditions than any other cereal, though it reaches its best development in warm, dry climates. Barley belongs to the same tribe as wheat and rye. The chemical composition of the grain, after taking off the hull, is almost identical with wheat. It is one of the oldest of cultivated crops. Down to the sixteenth century it was the chief bread plant of Europe, but since that time it has given way to wheat. Its chief use in America is as food for domestic animals and for malting purposes. In 1850 New York produced about 69.4 per cent of the barley grown in the United States. The North Atlantic division produced 81 per cent. In 1900 the center of production was the northern Missouri Valley, in Iowa and South Dakota. Nine States now produce about 91 per cent of the total yield, viz., California, Minnesota, Wisconsin, Iowa, South Dakota, North Dakota, Washington, New York, and Nebraska,[b] the first four pro-

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[a] See statement on Oat Crop of the United States prepared by C. W. Warburton for this report.

[b] See Cereals in America, by Thomas F. Hunt.

ducing three-fourths of the total crop. The world's production of barley for the past five years, 1903 to 1907, has been a little over 1,200,000,000 bushels. The acreage has gradually increased in the United States from 492,532 in 1866 to 1,131,217 in 1867, reaching 2,272,103 in 1882, 3,220,834 in 1889, falling a little below 3,000,000 from 1896 to 1900, then increasing to 4,295,744 in 1901, 5,145,878 in 1904, and 6,448,000 in 1907.

The yield per acre has fluctuated between 19.2 and 29 bushels, averaging, from 1867 to 1876, 22.8 bushels; from 1877 to 1886, 22.4 bushels; from 1887 to 1896, 22.7 bushels; and from 1897 to 1906, 25.5 bushels.

The farm value has been gradually declining, but it increased in 1907 to 66.6 cents, the highest since 1881.

Varieties.—There are two well marked types of barley, the six-rowed and the two-rowed, both of very ancient cultivation and possibly representing separate species. An intermediate form (*Hordeum vulgare L.*) is the common four-rowed barley. The two-rowed varieties of the Hanna and Chevalier type appear to be better adapted to the drier Northwest; while the six-rowed varieties, like Oderbrucker and Odessa, do better in the moister regions. North of the forty-third parallel it is necessary to sow in the spring, but south of this line fall sowing is rapidly coming into favor, especially since 1903, when the Department of Agriculture began to demonstrate the superior value of the winter strains, which yield on an average 25 to 30 per cent more than the spring sorts south of the forty-third parallel. The principal reason is that the fall-sown grain ripens before the hot summer weather arrives. Drilled winter barley in Indiana, Illinois, and Ohio has stood the winter better than broadcasted barley, two-thirds of the loss from winter killing being prevented by this method.

Several years ago the Department of Agriculture introduced a considerable number of hull-less and beardless barleys from the high plateaus of the Himalaya Mountains in Asia and distributed them through the Rocky Mountain States. Their success has been phenomenal. Their cultivation has been successfully carried up to nearly 9,000 feet, where they give valuable hay as well as grain. Large quantities are grown under irrigation in the mountain sections of Montana, Wyoming, and Colorado. They have also been found to be well adapted to the semiarid area of the Great Plains, proving to be one of the best dry-land crops. Like wheat, oats, and corn, and, in fact, most other crops, the barleys do best in soils rich in humus and decaying organic matter. They decline rapidly in yield if the humus and organic matter is not maintained, being more sensitive than other cereals in this respect. In the rich tule lands of California a yield of 80 to 90 bushels per acre is often secured, and under favorable conditions nearly as high yields are often secured in the northern Mississippi Valley. Under average conditions, however, 35 to 40 bushels is considered a fair yield. This is from 10 to 15 bushels above the average for the last decade for the principal barley area and from 15 to 20 bushels above the average for the South. As better rotation methods and cultural methods generally come into use the average yield of this crop, like that of all others, gradually increases.

RYE.

The acreage of rye in the United States has fluctuated between one and a half million and two million acres from 1866 down to the present. The average yield per acre declined slightly down to the beginning of the last decade, during which there has been an average increase of 3 bushels per acre (13.6, 13.0, 12.9, 15.7). The farm value has fluctuated considerably, falling as low as 40.9 cents in 1896, ranging between 50 and 60 cents during the last ten years, reaching 68.8 cents in 1904 and 73.1 cents in 1907. The exports fluctuate greatly.

From the standpoint of its grain value, rye is the least profitable of our cereal crops. It is, however, adapted to very light, poor land, and will make a fair crop where other cereals, with the exception of emmer (sometimes erroneously called "spelt"), would fail. Like the other cereals, however, it responds to better soils or to fertilization.

On account of its great hardiness and its ability to grow on poor soils, it is largely used as a green manure crop.

There is a great demand for rye straw for paper and for other purposes, and, except where it is grown for green manure, it is grown principally for the straw. The grain makes a good flour for human food, but in this country it is not much used except for domestic animals and for brewing purposes.

The yield could be greatly increased, if desired, both by the use of better cultural methods and by selection of high-yielding strains.

RICE.

This is a cereal crop especially adapted to wet soils where other cereals will not grow. The genus *Oryza* is tropical, and there are a number of species of the genus growing wild in the Tropics of both hemispheres. A closely related genus, *Zizania*, is widely distributed in semitropical and northern countries. *Z. aquatica* occurs extensively in marshy places throughout North America and northeastern Asia. In North America it was extensively planted in marshes and used by the Indians as food. The southern wild form of the Gulf States, *Z. miliacea*, is used only for hay.

The cultivated rices originated in southern Asia in prehistoric times. There are five principal groups, corresponding possibly to species, indigenous to southern Asia, especially China. Like other cereals, there are a great number of varieties or strains adapted to a great variety of conditions, both upland and aquatic. One hundred and sixty-one varieties are recognized in Ceylon alone, and about 1,400 in China, India, and Japan. Only a few varieties have been introduced into culture in the United States, though about 800 are under test by the Department of Agriculture.

The principal areas in the United States devoted to rice are (1) the delta land and inland marshes of the South Atlantic States, (2) similar land along the Gulf coast and the southern Mississippi River, and (3) the prairie soil of southwestern Louisiana and southeastern Texas. The prairie rice culture is much like that of wheat or oats. The upland rices, however, are not as good in quality or as high yielding as those grown under irrigation, and, while it can be grown on any soil that will produce corn or cotton within the cotton belt, it will not compete with other grains on these soils as a rule. Where irrigation is practicable, as it is in some of the prairie regions of southwestern Louisiana and southeastern Texas, systems of irrigation and culture have been developed by which it is possible to use the same machinery as is used in cultivating wheat, thus greatly lessening the labor cost as compared to culture in swampy areas, which can not be drained sufficiently to permit the use of such machinery. The following table, taken in part from Farmers' Bulletin 110, shows the difference in labor cost for the United States as compared with other countries:

Number of acres one man can farm in rice, with wages, in different countries.[a]

Countries.	Acres.	Farm wages, in gold per year, with board.
Japan	½	$10 to $18
China	½ to 2½	8 to 12
Philippines	2½	15 to 20
India	3	10 to 20
Siam	3	10 to 20
Egypt	4	15 to 30
Italy	5	40 to 60
Spain	5	40 to 60
United States:		
Carolinas	8	96 to 120
Mississippi Delta	10	120 to 144
Southwestern Louisiana and Texas	80	180 to 216

[a] Farmers' Bul. No. 110, p. 19. U. S. Dept. Agr., 1900.

The following table shows the acreage, production, and value of rice in the United States in 1907, by States:

Acreage, production, and value of rice in the United States in 1907, by States.

State.	Area.	Average yield per acre.	Production.	Average farm price December 1.	Farm value December 1.
	Acres.	*Bushels.*	*Bushels.*	*Cents.*	*Dollars.*
North Carolina	1,000	23.0	23,000	91	21,000
South Carolina	19,100	27.0	516,000	107	552,000
Georgia	2,400	34.0	81,000	105	85,000
Florida	2,300	30.0	69,000	110	76,000
Alabama	1,400	25.0	35,000	95	33,000
Mississippi	1,100	22.0	24,000	90	22,000
Louisiana	310,000	28.0	8,680,000	85	7,378,000
Texas	284,000	32.0	9,088,000	85	7,725,000
Arkansas	6,000	37.0	222,000	85	189,000
United States	627,300	29.9	18,738,000	85.8	16,081,000

The yields have been greatly reduced in the Carolinas by a disease known as "blast." It is believed that varieties resistant to the disease can be developed. The same disease has appeared in the rice areas of Louisiana and Texas, where it is already causing considerable trouble. The introduction by the Department of Agriculture of better milling and better yielding varieties, especially the Kiushu, greatly stimulated the culture of this cereal in the Louisiana and Texas prairies.

According to Knapp, there are about 10,000,000 acres of land in the five States bordering on the Gulf of Mexico well suited to rice cultivation. Only about 3,000,000 acres of this, however, can be irrigated and cultivated by machine methods. As rotation systems will be required in order to control weeds and keep up the humus supply, only about one-half of this would be devoted to rice in any one year. The present acreage devoted to rice, as shown in the table just cited, is 627,300, with an average production of 29.9 bushels, or 18,738,000 bushels. Besides this the United States annually imports over 120,000,000 pounds of rice. The amount has been gradually increasing, being over 200,000,000 pounds in 1906. It is evident, therefore, that the demand for rice is increasing. If the million and a half acres available for rice each year in the South should be put into this crop and the yield should be about the average of 10 barrels (162 pounds) per acre, the product would amount to 2,500,000,000 pounds of cleaned rice, nearly six times the amount of our present consumption. It is evident, therefore, that this food resource has great potential value and can fully keep up with the demand at remunerative prices. As Knapp[a] states in Farmers' Bulletin No. 110:

> The employment of machinery in the rice fields of the Southwest similar to that used in the great wheat fields of California and the Dakotas is revolutionizing the methods of cultivation and greatly reducing the cost. The American rice grower, employing higher-priced labor than any other rice grower of the world, will ultimately be able to market his crop at the least cost and the greatest profit. If, in addition, the same relative improvement can be secured in the rice itself, if varieties which yield from 80 to 90 per cent of head rice in the finished product can be successfully introduced, American rice growers will be able to command the highest prices for their product in the markets of the world. In view of the success in this direction of the Kiushu rice, experimentally introduced by the Department of Agriculture, more than 100 tons of this rice were ordered from Japan by Louisiana planters for the season of 1900.

SORGHUMS.[b]

All of the sorghums now in cultivation probably originated from a wild species native in tropical Africa.

The sorghums grown in this country may be separated into four groups—(1) the broom corns, (2) sorgo, or sweet sorghums, (3) kafirs, and (4) durras. The broom corns are grown only for their brush. The sweet sorghums are grown for forage and sirups, the kafirs for grain and forage, and the durras principally for grain. The last two groups are generally known as the nonsaccharine sorghums and are especially adapted to the hot, dry, or semiarid sections of the West and Southwest. All the varieties are very resistant to alkali. The durras are especially alkali and drought-resistant and adapted to higher altitudes. They are taller and less leafy than the kafirs. While the kafirs are most largely grown and have the widest adaptation, some of the improved strains of durra or milo are coming into prominence in the drier areas of the Great

[a] Rice Culture in the United States, by Dr. S. A. Knapp, Farmers' Bul. 110, U. S. Dept. Agr.

[b] See Farmers' Bul. 135, Sorghum Sirup Manufacture; 174, Broom Corn; 246, Saccharine Sorghums for Forage; 288, The Nonsaccharine Sorghums; 322, Milo as a Dry Land Grain Crop; and Cereals of America, by Hunt.

Plains, especially western Texas, New Mexico, Oklahoma, and Kansas.

The ordinary so-called dwarf milo obtainable in the market is the type usually grown, but on account of its lack of uniformity in height of seed heads and bending of the heads it is very difficult to handle by machinery. Improved strains, nonsuckering and uniform, with upright heads and light yellow seeds, have been developed and are being distributed by the Department of Agriculture. These are handled easily by the ordinary harvesting machinery and yield from 25 to 55 bushels of grain per acre. Its value for stock food is slightly less than that of corn, containing a slightly smaller percentage of protein and half the percentage of fat. In tropical countries, however, the sorghums are almost as largely used for human food as rice. In this country their use as human food is principally as griddle-cake flour.

The principal value of the sorghums to the United States lies in their adaptation to conditions where other grain and forage crops are more difficult to produce. The opportunities for improving and adapting the various strains are very great.

It is doubtful whether the sweet varieties can ever compete with sugar-cane and beets for sugar manufacture. They may prove, however, to be a valuable crop for the manufacture of denatured alcohol. As a soiling crop and for hay and silage mixed with legumes the sweet sorghums are superior to the nonsaccharine sorts, though the latter are now principally in use.

It is not a perfectly safe pasture plant on account of the prussic acid likely to develop in second-growth plants or plants which have been frosted or otherwise checked. Sorghum is, however, extensively used for pasture.

BUCKWHEAT.

Buckwheat belongs to the smart-weed family and is adapted to poor soils and short cold seasons. It grows wild on the banks of the river Amur in Manchuria, in Dahuria, and near Lake Baikal. It has long been cultivated in China, northern India, and in the Himalaya Mountains. The species came into central Europe in the middle ages through Tartary and Russia. It was early introduced into America and is quite extensively cultivated in New York, Pennsylvania, Michigan, Wisconsin, and Maine, these States producing four-fifths of the crop in 1899. The acreage and production have been about constant since 1870, when the acreage fell from a little over 1,000,000 to a little over 500,000. It reached 800,000 in 1880, and has fluctuated about this figure to date. The average yield, in bushels, per acre in the United States for 1866 was 21.8 bushels; in 1867, 17.4; for the decade 1868–1877, 17.4 bushels; for the decade 1878 to 1887, 14.1 bushels; 1888–1897, 16.2 bushels; 1898–1907, 17.8 bushels. The table[a] on the following page shows the acreage, production, and value of buckwheat in the United States in 1907, by States.

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[a] Yearbook, U. S. Dept. Agr., 1907, p. 649.

Area and value of buckwheat in the United States in 1907.

State.	Area.	Average yield per acre.	Production.	Average farm price December 1.	Farm value December 1.
	Acres.	*Bushels.*	*Bushels.*	*Cents.*	*Dollars.*
Maine	23,000	28.0	644,000	65	419,000
New Hampshire	2,000	22.0	44,000	75	33,000
Vermont	8,000	22.0	176,000	70	123,000
Massachusetts	2,000	21.0	42,000	70	30,000
Connecticut	3,000	16.0	48,000	75	36,000
New York	325,000	17.5	5,687,000	70	3,981,000
New Jersey	12,000	16.5	198,000	75	149,000
Pennsylvania	257,000	18.0	4,626,000	69	3,192,000
Delaware	1,000	24.0	24,000	69	17,000
Maryland	9,000	19.0	171,000	67	115,000
Virginia	18,000	19.0	342,000	73	250,000
West Virginia	21,000	18.5	388,000	75	291,000
North Carolina	5,000	15.5	78,000	71	55,000
Ohio	13,000	19.5	254,000	75	191,000
Indiana	4,000	15.5	62,000	73	45,000
Illinois	4,000	17.0	68,000	80	54,000
Michigan	55,000	15.5	852,000	65	554,000
Wisconsin	20,000	16.0	320,000	72	230,000
Minnesota	5,000	14.7	74,000	73	54,000
Iowa	9,000	15.0	135,000	80	108,000
Missouri	1,000	16.0	16,000	90	14,000
Nebraska	1,000	14.5	14,000	88	12,000
Kansas	1,000	12.0	12,000	82	10,000
Tennessee	1,000	15.0	15,000	80	12,000
United States	800,000	17.9	14,290,000	69.8	9,975,000

Under favorable conditions, buckwheat will mature a crop of seed in from eight to ten weeks. It will grow at higher altitudes and farther north than any other grain crop. It is not affected by diseases or insects, but is very sensitive to heat and drought. The Japanese variety is the hardiest strain, which with Silver Hull and Common Gray are the types commonly grown in the United States. The flour is used principally for pancakes and as food for hens. Its average farm value is about $11 per acre.

IMPORTANCE OF CEREAL CROPS.

On account of the relatively important position that cereal crops have occupied in the past and always will occupy in the agriculture of the world they have been chiefly discussed individually. The comparative areas and value of cereals in the United States as compared with other field crops is shown in the following table compiled from the Twelfth Census by Hunt:[a]

Area and value of field crops in the United States in 1899.

	Area (acres).	Value of crops.	Value per acre.
Cereals	184,994,588	$1,484,231,038	$8.02
Hay and forage	61,691,166	487,125,685	7.93
Legumes for the seeds	1,964,634	28,308,228	14.36
Tubers	2,938,952	98,387,614	33.47
Roots	537,447	19,876,200	36.98
Sugar plants	855,995	51,367,685	60.01
Fibers	26,401,660	390,879,985	11.02
Stimulants	1,101,483	56,993,003	51.74

[a] The Cereals in America, by Thomas F. Hunt, p. 3.

Of the total area in hay and forage crops, 6.7 per cent was devoted to clover, 50.7 per cent to tame and cultivated grasses other than clover, 6.3 per cent to grains cut green for hay, 5.1 per cent to forage crops, 3.4 per cent to alfalfa, 2.8 per cent to millet and Hungarian grasses, and 25.1 per cent to wild, salt, and prairie grasses.

The acreage, production, and value of the eight cereals in 1899, and percentage of the total contributed by each, are shown in the following table, taken from the Twelfth Census:[a]

Grain.	Acres.	Bushels.	Value.	Per cent of total acreage.	Per cent of total yield.	Per cent of total value.
All cereals	184,994,588	4,434,698,746	$1,484,231,038	100.0	100.0	100.0
Corn	94,916,911	2,666,440,279	828,258,326	51.3	60.1	55.8
Wheat	52,588,574	658,534,252	369,945,320	28.4	14.8	24.9
Oats	29,539,698	943,389,375	217,098,584	16.0	21.3	14.6
Rye	2,054,292	25,568,625	12,290,540	1.1	.6	.8
Barley	4,470,196	119,634,877	41,631,762	2.4	2.7	2.8
Buckwheat	807,060	11,233,515	5,747,853	.4	.3	.4
Rice	351,344	4,728,710	7,891,613	.2	.1	.6
Kafir corn	266,513	5,169,113	1,367,040	.2	.1	.1

HAY AND FORAGE CROPS.

According to the last census, the total improved farm area in the United States in 1899 was 414,000,000 acres, of which nearly 290,000,000 acres were in crops of all kinds. The difference, approximately 125,000,000 acres, was probably devoted to pasture. This, in addition to the area utilized for cultivated grasses and forage crops, makes the area devoted to these classes of plants nearly 189,000,000 acres—approximately 4,000,000 acres greater than that devoted to all the cereal crops combined. A considerable portion of this land, now in wild grasses and pastures, has in some States formerly been cultivated to cereal and other crops and could now be utilized for that purpose, if necessary, or if such utilization were more profitable than their use for pasture. In some States a considerable portion of this land is mountainous or swampy and under present conditions would probably be utilized only for pasture and hay crops. The percentage of the land thus devoted to wild pasture and hay crops is shown in the census report and the statistics will therefore not be repeated here.

The largest increase in the utilization of this wild-grass land for cultivated grasses and forage has occurred in the West and in the South. In the South the increase is due largely to the fact that large areas which were formerly in many cases under cultivation have been allowed to run wild for long periods, but with the general agricultural progress of the South, the development of stock raising, and the diversification of crops, these lands are being utilized for cultivated hay and forage crops. The production per acre in the Southern States has increased faster than the acreage, which is the result of the use of better agricultural methods, especially the more general use of leguminous crops and fertilizers.

The rapid development of the use of unimproved grass lands for cultivated forage is coincident in nearly all the States with an increase in the live-stock interests, as shown by the census reports. The

[a] Twelfth Census of the United States, 1900, Vol. VI, Agriculture, pt. 2, p. 14.

general summaries, showing the acreage and value of hay and forage crops, compared to the value and acreage of all crops, and the acreage of improved land, is here included to show the very great importance of the hay crops:[a]

States and Territories.	Acreage of hay and forage.	Acreage of all crops.	Acreage of improved land.	Per cent of acreage of—	
				All crops in hay and forage.	Improved land in hay and forage.
The United States[a]	61,691,166	289,821,549	414,793,191	21.3	14.9
North Central division	35,676,042	163,000,561	222,314,099	21.9	16.0
North Atlantic division	12,919,041	24,683,365	38,920,614	52.3	33.2
Western division	7,051,123	16,622,861	27,155,681	42.4	26.0
South Central division	3,883,662	56,233,143	80,007,867	6 9	4.9
South Atlantic division	2,161,201	29,194,661	46,100,226	7.4	4.7

States and Territories.	Value of all crops.	Value of hay and forage.	Percentage value of all crops in hay and forage.	Average value per acre of—		Percentage of total value of hay and forage.
				All crops.	Hay and forage.	
The United States[a]	$2,910,138,663	$484,256,846	16.6	$10.04	$7.85	100.0
North Central division	1,373,021,966	221,866,406	16.2	8.42	6.22	45.8
North Atlantic division	374,955,069	141,959,434	37.9	15.19	10.99	29.3
Western division	192,668,844	60,839,199	31.6	11.59	8.63	12.6
South Central division	617,822,833	30,663,233	5.0	10.99	7.90	6.3
South Atlantic division	330,370,926	26,926,431	8.8	11.32	13.38	6.0

[a] Data for Alaska and Hawaii included in totals for United States, but not in those for the 5 geographic divisions.

The hay and forage crops are made up of a very large number of both wild and cultivated species. On the ranges of the West, and to a considerable extent in the North Central States and the Southern States, wild grasses enter into the composition of the hay, even on lands that are under cultivation. There are about 3,500 known species of true grasses, divided into about 300 genera. Of this number there are in the United States 1,380 species (1,275 native and 105 introduced), divided among 165 genera. Scribner estimates that 38 of these grasses have earned a high reputation as hay grasses, 35 as pasture grasses, 14 as lawn grasses, and 24 as grasses for wet lands, 20 for embankments, and 19 for holding shifting sands, the same grass occasionally occurring in the different categories.

In the census returns the true grasses are listed as (1) wild, salt, and prairie grasses, the total acreage amounting to nearly one-fourth of all the acreage producing hay and forage; (2) the millet and Hungarian grasses, grown especially in the North Central and South Central divisions, but to some extent throughout the United States. The total area reported in this class of grasses was a little under 2,000,000 acres, producing nearly 3,000,000 tons.

Among the millets and Hungarian grasses the best known are the foxtail or common millets, the broom-corn millets, barnyard millet, and pearl millet. The former are the most commonly cultivated, and

[a] Twelfth Census of the United States, 1900, Vol. VI, Agriculture, pt. 2, p. 213.

all of them produce not only a large amount of forage but large quantities of grain. The millets are all hot-weather plants, but are exceedingly drought-resistant. They will grow luxuriantly on poor soils, but respond well to richer soils. Many of these grasses could be easily improved both for seed production and for forage and hay, but so far very little attention has been given to them.

Para grass.—Recently Para grass, a South American *Panicum*, has given excellent yields along the Gulf coast and in Florida. Its culture is rapidly extending westward, especially in southern Texas. It has a great advantage over Bermuda grass or Johnson grass, as its runners are on the surface and can be easily destroyed, whereas in the grasses mentioned the runners have a tendency to go rather deep, so that they are difficult to eradicate from cultivated land and, for that reason, are much in disfavor. The Para grass, however, can not stand much cold at the present time. It will doubtless, however, gradually be pushed farther north and may become one of the most valuable forage and hay grasses for moist or wet lands. In Florida Para grass has carried as high as 6 head of cattle per acre for eight months of the year.

Guinea grass.—This is a closely related species introduced from Africa. It grows more as a bunch grass, is adapted to drier lands, and is a highly prized grass, especially in Florida, Alabama, and Mississippi.

Crab-grass.—The crab-grass of the South, though considerable of a weed, makes excellent volunteer forage and very good hay.

Bermuda grass.—The most common lawn and pasture grass of the South is the Bermuda grass. It produces a very fine quality of hay, is an excellent sand and soil binding grass on account of its strong rootstocks, stands pasturing well, and is quite resistant to cold.

Bluegrass.—In the North the Kentucky bluegrass is the principal cultivated pasture grass and lawn grass. It is especially adapted to limestone soils.

Timothy and redtop.—In the North the principal hay grasses are timothy and redtop, the former adapted to the higher and drier lands, and the latter to the moister situations.

Other wild grasses.—In the West the principal wild grasses are the blue and white grama, mesquite, buffalo, and the bunch grasses, the big bluestem, and the western wheatgrass. A large number of other genera and species, however, are of great importance as adapted to special conditions, especially to high altitudes, to alkali, and to withstand drought, many of the most valuable species, like buffalo grass, curing as they stand on the ground, making an excellent winter feed.

As previously stated, many of these wild grasses have been almost destroyed in parts of the range country, owing to overstocking, but it has been found that, if the range is rested and if the wild grasses are allowed to seed for a few years, they can easily come back to their former luxuriance. Observations made by Mr. Coville in connection with the Forest Service show that it is often necessary to keep the stock off the range only for a short period, while the more important grasses are forming their seed. After the seed is formed, the range may be again used without serious injury to the grass flora. Taking advantage of this fact promises to be one of the most important elements in range management.

Great improvements can be made by selection, not only in our native grasses, but in the introduced species. Their value and adaptation to certain areas can by this process be very greatly increased. Grasses respond also readily to fertilizers, especially to nitrogen and phosphates.

Next to the legumes, the grasses are the most important soil-improving crops, provided a considerable portion of the stubble or the sod is occasionally turned under or allowed to rot on the ground, thus forming humus. Under these conditions in limestone soils, if the proper bacteria are present, large quantities of atmospheric nitrogen are fixed by the bacteria, the carbon required in the process being furnished by the dead grasses. None of the grasses, however, so far as known, have symbiotic bacteria growing on their roots, as in the case of legumes.

LEGUMINOUS FORAGE CROPS.

Clover.—Of the leguminous forage crops, the most important are the clovers in the Northeast and North Central sections, cowpeas in the Southeast and South Central States, and alfalfa in the West. There are about 250 species belonging to the true clovers, genus *Trifolium*, about 65 of which are native in North America, the greatest number being in the Western States. Many of these are extremely valuable as elements in the native forage and as soil-improving, nitrogen-fixing crops.

The most valuable cultivated species, however, are the introduced varieties—red clover, mammoth clover, crimson clover, alsike, and berseem. Of these the red clover is the most important and the most widely cultivated. It has many strains as the result of cultivation under different conditions, but up to the present time very little attention has been given to selecting and adapting varieties to localities.

Clover requires a well-drained soil containing considerable lime. It is extremely sensitive to acid reaction in the soil or to a lack of potash or phosphoric acid. It also requires, like the other legumes, certain types of bacteria, which form nodules on the roots and secure nitrogen from the air for the use of the plant. Occasionally these bacteria are not present in the soil or are of reduced vitality or nitrogen-fixing power, and clover fails to do well until the soil is reinoculated.

In the South a root and stem disease has destroyed large areas of red clover, and the disease, living in the soil, prevents the growth of clover on those soils. The Tennessee station has found that strains resistant to this fungus can be developed, and such selected strains of clover grow well in soils where the ordinary types die out completely. The large number of species of clovers which hybridize readily makes it possible to produce strains adapted to a very wide range of conditions and agricultural requirements.

Crimson clover is cultivated especially in the South Atlantic States north of the cotton belt and south of the fortieth parallel. It is grown principally as a cover crop in orchards for soil improvement.

In the Southern States the principal legume grown for hay and for soil improvement, as well as for the seed, is the cowpea. There is a large number of varieties of cowpea, probably originally developing from a single species, *Vigna sinensis* (a bean rather than a pea). Unlike the clovers, the cowpeas are well adapted to soils inclined to be acid, but are, nevertheless, prolific nitrogen fixers, provided they are supplied with the proper bacteria. The cowpea, however, is peculiarly subject, on light soils, to attacks from the nematode rootworm, causing galls on the roots, and to a disease known as wilt. The culture of varieties susceptible to these diseases is likely to infect the soil to such an extent that other crops sensitive to these diseases can not be developed, and even the peas themselves fail to grow. The only crops not injured by root-knot are the grasses and grains. The disease is very injurious to vegetables, fruit trees, and cotton, and many thousands of acres have been practically ruined for these crops by the development of nematodes in connection with the cowpea. As the cowpea, however, is absolutely essential as a soil-improving crop, it was necessary to find a strain resistant not only to the nematode but to the wilt. This was accomplished in the variety known as "Iron," which is extremely resistant to both diseases and can be used with perfect safety on soils infected with the diseases or without danger of introducing disease to soils not infected. The Iron cowpea, therefore, is the key to the improvement of the lighter, sandy soils in practically all the Southern States. Its resistant qualities have now been bred into a number of other strains of cowpea, but these have not yet come into commercial use. It is possible, however, to produce resistant strains which give high yields of hay and seed and which are adapted to the various localities. Much interest is now being taken by experimenters in this work.

Alfalfa or lucern (*Medicago sativa*).—This is the most important leguminous hay and forage plant of the West. It was introduced into California from Chile in 1854, and spread first through the irrigated sections. Some of the varieties are especially adapted to irrigated lands, on which they give extremely high yields. It has been grown more or less in every State of the Union, although it is only in the West and Southwest that its culture has reached large proportions. Until very recently alfalfa was supposed to be practically one species, but more careful study has shown that there are probably several species and a very large number of varieties, much of the commercial seed being considerably mixed.

The ordinary alfalfa or purple lucern is widely cultivated all over Europe and Asia and has hybridized to some extent with other species native in those regions, especially with the yellow form, *Medicago falcata*, growing in the north of Europe. The latter species has yellow flowers and is extremely cold resistant. These hybrids, known as *Medicago media*, combine the fine hay qualities of the ordinary alfalfa with the cold and drought-resistant qualities of the yellow northern form and are thus much better adapted for growth in such localities. Some of these hybrids are known under the common name of sand lucern and are found to be well adapted to northern Michigan, Minnesota, the Dakotas, and Montana. A similar intermediate form has been found in Turkestan, and is probably a hybrid between the yellow form of northern Siberia and the dry-land strains of the ordinary alfalfa growing in Turkestan.

Alfalfa adjusts itself to climates and soils with considerable facility and, where it has long been cultivated under peculiar climatic conditions, it adapts itself to these conditions. Extremely valuable sorts or strains may thus be secured from many Old World localities, and these strains when introduced into similar conditions in the United States are proving of more value than the ordinary unadjusted or unadapted sorts. It is absolutely essential, however, in introducing these strains to know the exact conditions to which they are adapted; otherwise they will simply break up and require acclimatization again. An American adaptation of this kind has been found in northern Minnesota and has been distributed under the name of Grimm alfalfa. This is an acclimatized strain of ordinary alfalfa, possibly having a slight admixture of the northern yellow species *falcata*. In any case, it is an extremely valuable cold-resistant sort.

A strain of alfalfa secured in an oasis of the Sahara Desert is extremely alkali resistant and may prove valuable for such locations.

A careful study of the varieties and adaptations of this important class of leguminous crops is now being made by the Department of Agriculture, experiment stations, and practical farmers, and great improvements will undoubtedly soon be made in the adaptation of these varieties to varying conditions. There is no doubt that strains well adapted to culture in the Eastern and Southern States can be developed. The alfalfas are perennial, deep-rooted crops, strong nitrogen fixers when supplied with the proper bacteria, and extremely valuable not only for forage and hay but as soil improvers, making large amounts of humus and fixing large quantities of atmospheric nitrogen.

The nodule bacteria adapted to alfalfa are rather more sensitive to unfavorable soil conditions than the types adapted to other legumes, and greater difficulty is therefore found in inoculating seed for sowing in areas where the germ is not present. For this reason inoculation with soil has proved more certain in many cases than culture inoculation, and where soil can be obtained free from injurious weeds or diseases this method is to be recommended.

The worst pests of alfalfa, however, are weeds, especially the dodders and wild barleys and other grasses. The alfalfa leaf-spot and anthracnose (the same disease which attacks clover) are often quite destructive in the Southeastern States, where root nematodes also do considerable damage to this crop. In the Southwest the root-rot, *Ozonium*, which attacks cotton, also attacks alfalfa, and, as all these pests are readily distributed through soil, it is considered a dangerous practice to distribute soil for the purpose of inoculation, except from very carefully controlled fields, which are hard to find. The Department of Agriculture supplies pure cultures, and with a little care these can usually be made to work satisfactorily. Wherever sweet clover grows the sweet-clover germ present in the soil works satisfactorily on alfalfa, so that inoculation is not usually necessary.

The vetches.—Two of the twenty or more species of vetches have been used considerably in this country as cover crops and for soil improvement and hay—spring vetch or tare (*Vicia sativa*) and the winter, hairy, or sand vetch (*Vicia villosa*). The former is cultivated to some extent in New England and in Washington, Oregon, and California. The winter vetch, or hairy vetch, is much better adapted to the agricultural requirements of a winter cover crop than the former species and is coming to be widely used for that purpose.

Very cold-resistant strains of this winter vetch have been introduced from northern Europe and have been adjusted to the conditions in New England. It also grows quite successfully through the Middle States and the South. It produces a mass of fibrous roots, which when inoculated produce abundant root tubercles. It does not seed well unless inoculated. Although it does best on good soil it makes an excellent growth on poor sandy, gravelly soils, where it produces a heavy growth of nodules.

The importance of inoculation on poor soils is shown by the results secured at the Alabama station. Without inoculation it produced only 232 pounds of hay per acre, but with inoculation it produced 2,540 pounds. At the Cornell station over 6,800 pounds of air-dried forage per acre were produced in three months, and even higher yields than this have been produced in many localities. This winter vetch is not only cold resistant, but also resists drought and is not subject to serious injury from diseases or insects. It is, therefore, one of the most promising of our winter cover crops both from the standpoint of soil improvement and forage as well as hay.

Other valuable legumes.—In the cotton States the velvet bean (*Mucuna utilis*), the Florida beggarweed (*Desmodium tortuosum*), Japan clover (*Lespedeza striata*), and the bur clovers (*Medicago maculata* and *M. denticulata*) are all valuable cover crops.

A large number of other legumes, both native and introduced, are being experimented with by department and experiment station workers, and it is believed that leguminous cover crops and soil-improving crops can be found for every locality and condition required. These, with the proper bacteria present, ought to supply not only the soil humus so necessary to the maintenance of fertility, but they should fix from the atmosphere the nitrogen required for our other cultivated crops and grasses. The improvement of these leguminous cover crops is rapidly being pushed, and as agricultural conditions settle down to greater permanence their use in rotations will be greatly increased.

In this connection should be mentioned also legumes grown for seed. These are also valuable soil improvers, as, after the seed is gathered, the hay can either be used for stock feeding or turned under. All of the legumes already mentioned are more or less grown for seed, but in addition to these the common pea in its various varieties, the cowpea, the soy bean, peanut, and horse bean (*Vicia faba*) are all largely cultivated. There is a very great number of varieties of these crops adapted to different conditions, all of which can be very greatly improved by breeding and selection.

SUGAR-PRODUCING CROPS.

Sugar beets.—Of the root crops the most important are the various varieties of beet. Some of the white varieties of beet contain high percentages of sugar and are cultivated under the name of sugar beets, especially in the North Central and Northwestern States, where the days are cool and bright. Formerly the seed for the highly selected strains of sugar beets was imported, but in late years, through the effors of the Department of Agriculture, strains have been developed specially adapted to the northwestern conditions, which give better results than imported seed.

The principal drawback to sugar-beet culture in the United States is the large amount of hand labor required in thinning the beets, as the seed balls have from two to five germs in each ball and all but one of these has to be broken off after the seed sprouts. The department has under way a breeding experiment for the production of single-germ seeds, so that each ball will produce but one sprout. Strains have already been secured which produce more than 60 per cent of these single-germ balls, and it is believed that ultimately strains of high sugar-producing sorts of beets can be developed which can be planted by machinery and thinned by machinery, thus greatly reducing the amount of labor in the culture of this crop. When this is accomplished, the industry of sugar-beet growing in the United States will be very greatly stimulated, and it is possible that not only our home demand for sugar can be supplied but that we can compete in the foreign markets.

Sugar cane.—The sugar cane of the South is also an important sugar-producing plant, but very little attention has yet been given to its improvement. From the results of work done in the West Indies and to some extent by experimenters in this country, it seems probable that considerable improvement can be made in the productiveness and unformity of American cane.

The soil and climatic conditions of Louisiana and the cane-growing sections are not as favorable to the growth of this crop as are those of Cuba, Porto Rico, Hawaii, and other tropical islands. The cost of drainage and the occasional cold waves, the high cost of seed cane, and the lower yield per acre in Louisiana, make the cost of sugar per pound very much higher than in the other countries named. Unless some improvement can be made in the methods of handling this crop in the Southern States it is doubtful if it can do much more than hold its own in competition with other cane sections now in possession of the United States. As shown by the census reports, the development of the sugar industry in Hawaii has been phenomenal since close trade relations have been established between the islands and the United States. With the development of irrigation works it is probable that considerable land not now cultivated can be brought under cultivation for cane and that the amount of sugar supplied by the islands can be considerably increased. The same is also true in Porto Rico, the Philippines, and Cuba.

According to the latest statistics gathered by the Department of Agriculture, the production of the cane sugar appears to be about just holding its own from year to year, while the production of beet sugar has considerably more than doubled in six years. The total annual consumption of sugar in the United States has reached nearly 3,000,000 long tons, and about 80 per cent of this is imported either from foreign countries or from the insular possessions of the United States. The total consumption of sugar has increased about 140 per cent, while the per capita consumption has increased 52 per cent since 1884. It is evident, therefore, that there is great opportunity for the development of the sugar industry not only in the United States but in our insular possessions.

Saccharine sorghums.—Another source of possible sugar production on the basis of farm crops is in the utilization of the saccharine sorghums. These have already been briefly referred to and attention called to the difficulties of obtaining from sorghum cane cheaply a good quality of sugar. The juice of the sorghum cane, as extracted by the mill, shows, in addition to sugar and water, considerable starch, dextrine, and soluble salts, which interfere with the crystallization of the sugar. Some of the better quality of cane, however, contains over 12 per cent of cane sugar and only 0.6 per cent of glucose. Almost no attention, however, has ever been given to the question of the careful breeding of canes for the purpose of cane-sugar production. With improvements in the methods of extraction which have been made in the past few years, especially through the efforts of the Department of Agriculture, and with the improvements which will be entirely possible as the result of careful selection and breeding, it is believed that the growing of sorghum cane for sugar will in the future be fully as profitable in the Southern States as the culture of beets in the Northern, and this crop may be considered as one of the important potential sugar crops of the United States. The cane is now cultivated in small areas on nearly 500,000 farms in the South, but it is used principally for sirup. These figures do not include a considerable acreage of the saccharine sorghums grown for forage. Nearly 17,000,000 gallons of sirup were produced in 1899, valued at over $5,000,000.

Maple.—According to the last census, the quantity of maple sugar made in the United States in 1899 was nearly 12,000,000 pounds and over 2,000,000 gallons of sirup.

FIBER CROPS.

Practically all of our cultivated plants produce more or less valuable fiber. The immense quantities of cornstalks now going to waste, in addition to what are used for other purposes, produce very valuable fibers for paper manufacture, and recent investigations and discoveries have led to the belief that the stalks may possibly be utilized to replace wood pulp now largely used in cheap paper manufacture. A method of separating the pith from the fiber cells has recently been discovered which appears to make the utilization of stalks for this purpose practicable.

Flax.—The oldest of our fiber plants is probably flax. Flax culture was early introduced into America, but has always been conducted along the most primitive lines. The farm methods have been crude and very irregular; the crop was grown year after year on the same soil without rotation, so that even at the present time the crop has no permanent place in the agriculture of the country. It is usually grown on new land for one year, sometimes two, after which the soil is said to be "flax sick" or exhausted, and the crop is moved to a new area. In this way it has been an important crop in a number of the older States, gradually moving westward to new lands, and is now centered in North Dakota and South Dakota.

The total area of flax in the United States is in the neighborhood of 3,000,000 acres (1907). There is considerable fluctuation in the acreage from time to time. In 1903 it was approximately 3,700,000. In this country flax is grown almost entirely for its seed for the purpose of extracting the oil. Between 25,000,000 and 30,000,000 bushels are annually produced, with an average yield fluctuating between 8 and 11 bushels per acre.

One of the principal reasons that the fiber has not been utilized has been the fact that the crop must under present agricultural conditions be grown on new land, and for that reason the center of production has been in constant movement from year to year. It has now been discovered, however, through the work of the North Dakota Experiment Station that flax sickness is not due to the exhaustion of the soil, but to the presence of one of the wilt fungi, a parasite which getting into the roots destroys the plants. This wilt fungus is very closely related to the one causing the wilt of cowpeas, cotton, and other crops in the South. A strain of flax resistant to this disease has been developed and produces excellent crops on infected soils where the ordinary flax will not grow. This promises to establish flax culture upon a firm basis, and, with the development of general farming systems, including rotation methods, and improvement of the fiber qualities of the flax, it is believed that strains valuable not only for oil but for fiber can be very profitably grown, at least in the moister portions of the North Central States.

The finest varieties of fiber require rather moist air and soil not subject to severe drought, and with a high humus content. It is probable, therefore, that the finest fiber flaxes will be produced in the moister portions of the country, while the oil or seed flax may be more successfully grown in the drier sections. However, even the straw in the drier regions can be utilized for tow, for paper pulp, binder twine, crash toweling, bagging, etc., and, as the industry becomes more stable, factories are developing to utilize the waste straw in this way.

COTTON.

The fiber plant of greatest importance, not only to America but to the entire world, is cotton. There are about 24 recognized species of cotton in different parts of the world. Many of the species cross readily, so that wherever they have been brought together there are many intermediate types. The American Upland cotton, which constitutes the bulk of the cotton of the world, comes from a species (*Gossypium hirsutum*) native in Central America. The plant is a perennial but both in its native habitat and in the United States it is cultivated as an annual.

Sea-Island cotton.—The Sea-Island cotton, *G. barbadense*, is apparently indigenous in the West Indies. It is of larger growth than the upland cotton and has a much longer and finer fiber. Its culture is practically limited to the moister coast regions of the South Atlantic States, the finest grades of it being produced on the sea islands in the neighborhood of Charleston and in the more healthful portions of the coastal plain in Alabama, Georgia, and northern Florida. The average production for the past seven years has been about 94,000 bales annually. The plant requires the most careful selection in order to maintain the high quality of the fiber. A few years ago many of the finest soils for this plant in the sea islands became unprofitable for the growth of this crop, the cotton dying before maturity. This was at first supposed to be due to the exhaustion of the soil in some particular, but investigation showed it to be due to a wilt fungus similar to that attacking cowpea, and resistant strains of Sea-Island cotton were bred which produced excellent crops even on the worst infected land. This again placed the industry on its feet, but the growers in the sea-island region have combined and allow no seed of their selected strains to be sold outside the district.

The sea-island growers outside the district have not been so progressive in the matter of selection, but are waking up to the necessity now that they can not secure seed from the Charleston district. Through the efforts of the Department of Agriculture it has been demonstrated that the strains for inland culture can be improved in the same manner as the Sea-Island strains and that wilt resistance, which is as fully if not more important in the interior districts, can be developed and maintained by selection.

The demand for Sea-Island cotton is somewhat limited, and excessive stimulation of production is therefore not desirable, as much reduction in price would make the crop unprofitable owing to the great care required in its production.

Egyptian cotton.—A closely related type of cotton, if not the same, is the Egyptian. The Egyptian cottons are cultivated principally in Egypt, but considerable quantities are imported into this country for special uses. The plant has now been acclimatized in the irrigated regions of the West and yields an average of a bale to the acre of a very good quality of fiber, but has not yet reached the stage of commercial production. About 100 bales will be marketed during the present season.

Long-staple Upland cotton.—The only other long-staple cottons produced in the United States are the so-called long staple Uplands now grown mainly in the alluvial delta region of Mississippi and Louisiana and to a limited extent in the rich valleys of the Red River in Texas and Louisiana and in similar localities in other cotton States. The crop of these cottons constitutes about 100,000 bales. The origin of the long-staple Uplands is probably the result of hybridization between the ordinary Upland cotton and the Sea-Island species. A number of fairly well-known strains are now in culture—Allen Hybrid, Allen Improved, Cook, Doughty, Griffin, Improved Long Staple, Mathews, Moon, and Columbia (the latter developed by the Department of Agriculture), Peeler, Southern Oak, Sunflower, and other varieties. Little attention has been given to the development of long-staple strains, as the premium paid for them has not been sufficient to warrant. The Sea-Island blood in them has had a tendency to make the long-staple strains rather late in maturing, which has not up to the present time been a drawback, but now that the boll weevil has such a firm foothold it will either be necessary to develop strains of the long staples of quicker maturity than those now grown or give up the culture of these cottons altogether, as production in the presence of the weevil demands quick maturity. The department has developed some hybrids between Upland and the long staples which appear to be as quick maturing as the Uplands and have done well in the river bottoms of southeastern Texas, maturing sufficiently early to escape serious injury from the weevil.

Upland cotton.—The great bulk of American cotton, however, as previously stated, comes from the Upland sorts, of which there is a large number. Cotton adjusts itself gradually to variations in soil and climate, and to secure the best results it is necessary to carefully select and breed seed in the region where it is to be grown. Almost no attention, however, has been given to this matter in cotton culture. The practice has been to get seed from the gin, and therefore mixtures of different strains were secured, often of poor quality and low yielding power, with the result that the average yield throughout the cotton States is very greatly below what it could easily be made by a little care in the selection of seed and the adaptation of the strains to the conditions of culture. Since the advent of the boll weevil much more attention has been given to this subject, and strains have been developed and improved both for quick-yielding and maturing qualities as well as for high quality of fiber or lint. Quick-maturing strains, like Triumph and King, have given very satisfactory yields even in the presence of the boll weevil, maturing the crop early enough to escape serious weevil injury.

In the original home of the American Upland cottons it has been found by department investigators that there are varieties of cotton having adaptations which enable them to resist weevil attack. The more promising strains of these have been brought into the country and are being tested both for their use in breeding and for their individual value for cultural purposes, and as these types were the originals from which the American cottons came, it is probable that some valuable characters can thus be secured, especially along the line of avoiding weevil injury.

Upland cotton is also subject in the Southeastern States in sandy soils to the same disease that attacks the Sea-Island cotton, namely, the wilt. The disease is quite widely spread and annually causes a large loss. Two types of Upland cotton resistant to this disease have been developed and are now being distributed by the department. These types give excellent yields on soils infected with the disease, as well as on other soils.

Cotton responds readily to selection and to better cultural methods. For many years the crop has been grown without rotation and with very shallow and imperfect cultivation and the use of large quantities of commercial fertilizer. All of these practices have resulted in the depletion of the soil humus to such an extent that the soil now packs and washes badly in nearly all the cotton States. It has been demonstrated, however, by good farmers and by numerous experiments by the state stations and the Department of Agriculture, that the plowing under of legumes and the use of barnyard manure and winter cover crops will quickly improve the soil by increasing its humus content, so that with much less commercial fertilizer it will produce more than double its present yield of cotton. These methods, coupled with more attention to the selection of seed, could easily raise the yield of cotton to more than double the present figures on the same acreage, and at the same time produce a number of other valuable money crops in rotation.

The United States now produces nearly 11,000,000 bales, which is more than 65 per cent of the total cotton crop of the world; British India produces something over 2,000,000 bales, a little over 14 per cent of the world's crop; Egypt produces a little over 1,000,000 bales, nearly 8 per cent of the world's crop; Russia, China, Brazil, Mexico, Peru, Turkey, Persia, and several other countries produce small amounts of more or less special types, for which there is a comparatively small demand. It is not probable that any other country will ever seriously compete with the American Upland cotton, especially if some attention is given to the improvements above suggested.

Miscellaneous fiber plants.—A large number of other fibers, including hemp, jute, ramie, etc., could be produced and are grown to some extent in the United States, but their importance has not been sufficient up to the present time to make them compete with other more valuable crops. Hemp is the most important of these and is grown to a considerable extent in Kentucky.

DRUG AND MEDICINAL PLANTS AND NARCOTICS.

The culture of drug and medicinal plants has not been developed extensively in the United States, but interest in this class of crops has been growing in recent years.

Camphor.—It has been shown that camphor can be profitably produced in Florida, the Carolinas, and possibly in Texas, and the beginning of an important industry in the growth of this tree is now apparent.

Opium poppy.—The culture of the opium poppy, which has heretofore been confined in this country simply to the production of poppy seed, will be stimulated to some extent by the discovery of a direct process of extracting morphine from the capsules, leaving out entirely the opium stage, which is so objectionable. This industry will be best adapted to the sections where the poppy is now grown principally for seed, namely, California, Oregon, and Washington.

Other drug plants.—A large number of other native and introduced drug and medicinal plants have been tested in different sections of the country and small industries in their culture will doubtless soon develop.

Tea culture.—Of the narcotics, tea has been commercially produced in South Carolina, and the extension of its culture will depend largely upon the development of machinery to supplement hand labor and reduce the amount of hand labor required. This has now been accomplished in practically all of the curing processes, and one of the department experts has about completed a pruning machine, and a picking machine will soon be developed which will practically reduce the production of tea to a machine basis. When this is accomplished it ought to become as important a crop in the South as tobacco.

Tobacco.—At the time of the discovery of America, tobacco was used for smoking, for snuff, and for chewing by nearly all the tribes of Indians in North America and Central and South America, including the West India Islands. There are about 50 species of the genus *Nicotiana* found in the wild state. All but two of these are found in America. The culture and use of tobacco undoubtedly originated in very early times on this continent, and from the earliest settlement it has been an important crop in several of the New England, Central, and Southern States. Practically all of the cultivated agricultural varieties originated from the species *Nicotiana tabacum* from South America. It is possible, however, that some of the strains may have the blood of a species which grows wild in Connecticut, New York, and Colorado, *N. rustica.* In the early days of the industry, especially in Maryland and Virginia, tobacco was grown year after year on the same land until the soil failed to give profitable returns, when the land was abandoned and allowed to grow up to brush and wood. Many thousands of acres of such old abandoned tobacco farms are still to be seen in these States now mostly covered with old field pine.

As tobacco is cultivated for the texture, size, and quality of the leaf, it is very greatly influenced by conditions of soil and climate, and the greatest care has to be exercised in the selection of soils for the production of the finer varieties, especially the cigar tobaccos. Most of the varieties now in cultivation are adaptations to peculiar soils and climates, and through long culture have come to be well-established types adapted to different uses. Among these may be mentioned the cigar-wrapper types, the cigar fillers, the chewing and plug, and the heavy export types.

Of the cigar-wrapper tobaccos the so-called Sumatra type, which produces a medium-sized, thin, elastic leaf when grown on light well-drained soils in the Connecticut Valley, Florida, and southern Georgia, is the standard. This variety produces the best grade of domestic cigar wrappers. It is grown under shade extensively in Florida and southern Georgia, and recently types have been secured which give satisfactory results in Connecticut. The so-called "Uncle Sam Sumatra," which is a strain of this type produced by the Department of Agriculture, is said to be the most uniform and highest yielding strain of Sumatra ever produced and is now cultivated extensively in Florida and to a considerable extent under shade in Connecticut. Connecticut Havana is a variety largely used for cigar wrappers and binders and the poorer leaves for fillers. It is adapted to light sandy soils when grown for wrappers, and to clay soils when grown for fillers. The light soils make the leaf thin and elastic, while the clay soils make the leaves heavier, thus producing a leaf better adapted for fillers. The Connecticut Broadleaf or Connecticut Seedleaf is a type very largely grown in outdoor culture in Connecticut and is adapted to sandy loam soils. The leaves are very broad, thin, and elastic and have small veins. The quality of wrapper and binder secured from this type of tobacco is not as good as that from the other types mentioned, although it has high yielding power and its adaptability for culture under northern conditions makes it a very desirable leaf for Connecticut, New Hampshire, Vermont, New York, Pennsylvania, Ohio, Wisconsin, and to a small extent in other States. Its quality has recently been very much improved in certain hybrid types between this tobacco and the Havana developed by the Department of Agriculture. It is believed that these new hybrids, which are now beginning to be grown in Connecticut and New York, will ultimately replace the old types.

Of the cigar-filler tobaccos the Cuban variety is the leading type adapted to sandy soils with a clay subsoil; has a small leaf of fine texture and produces a fine flavor and aroma. In the Connecticut Valley this type is also grown under shade for wrappers as well as fillers. Zimmer Spanish, which is probably a hybrid between the Connecticut seed leaf and a Cuban variety, is the principal cigar-filler tobacco grown in the Ohio Valley and Wisconsin.

Of the plug tobaccos the White Burley, the Orinoco, and Yellow Mammoth, and the Virginia tobaccos, Blue Pryor, Sun-Cured, and White Stem, are the leading types, grown especially in Kentucky, Ohio, Tennessee, and North Carolina.

Of the pipe tobaccos the bright yellow types of North Carolina and southern Virginia are leading sorts. These tobaccos are produced only on light sandy soils. On heavier, richer soils they produce a dark-curing leaf. The demand for this type of tobaccos is rapidly increasing, especially for export. The Maryland smoking tobaccos are largely export tobaccos. They develop best on clay loam and sandy soils. The leaves are thick and coarse in texture. The variety was discovered in Maryland when the first settlers explored the region and has extended from Maryland to Virginia and Pennsylvania, and from this type quite a number of important strains have developed in these States.

In recent years great attention has been given to the fertilization of tobacco, especially the finer wrapper and filler sorts. On account of the influence of soil on the quality of the leaf the tendency has been in all the areas producing the finer wrapper and filler tobaccos to grow the crop continuously upon the same land without rotation, and, although great care is used in the composition of the fertilizers, the tendency has been to use excessive amounts. The wrapper and filler types of tobacco do not grow to the best advantage on soils rich in carbonates, so that soils very rich in lime have to be avoided for this class of tobacco. In the Connecticut Valley the extensive use of carbonate of potash and other fertilizers containing carbonates has resulted in the accumulation of these to such an extent in the soil that the feeding roots of the tobacco have been slightly injured, making them sensitive to a fungous disease, which in the past few years has greatly reduced the yields over large areas. The fungus occurs commonly in leaf-mold and decaying organic matter and to some extent on injured roots of tobacco, but does no harm except when the soil becomes decidedly alkaline. It has been found that by using no lime on the diseased fields, applying potash in the form of the sulphate and using phosphoric acid in the form of the acid phosphate or dissolved bone, the alkalinity is overcome and the disease prevented.

The method of culture and fertilization followed has also in many soils very greatly reduced the humus content. This in some cases has been partially avoided by the use of barnyard manures, but on the finer types of leaf these manures stimulate too rank a growth. Experiments conducted in the past few years by the department have demonstrated that hairy vetch used as a winter cover crop for tobacco soils greatly improves the leaf texture, supplies the necessary nitrogen and humus, and improves the soil greatly for the production of the better types of leaf. Yields of over 7 tons of vetch per acre have been secured from inoculated seed. The nodule organism for vetch is not found in tobacco soils generally and the crop does not give good results except where the germ is supplied. Tobacco following uninoculated vetch shows but little advantage over that following a cover crop of rye. In comparative tests the inoculated crop yielded 7 tons as compared with the yield of 2 tons uninoculated, and the nitrogen content of the inoculated crop was very much higher than that of the uninoculated. Where a sufficient supply of humus is present in the soil the tobacco crop is not only larger but better in quality and more uniform.

In the South a bacterial disease has accumulated in some of the tobacco soils as a result of continuous culture without rotation, and in some places root nematode has developed to such an extent that the soils will no longer produce a profitable crop. In the latter case a resistant strain of tobacco has been produced by selection which grows well on nematode infected soils, but no strains resistant to the bacterial disease have yet been secured. The same bacterial disease also attacks potatoes and tomatoes, which are among the profitable crops grown on the same soils in Florida. It is useless, therefore, to rotate with these crops where this disease is present.

In the areas growing heavier types of tobacco, especially in Maryland, Ohio, Kentucky, Virginia, and the Carolinas, the principal problems involved in the improvement of the crops are along the line of rotation. The tendency is to cultivate tobacco too long upon the same land without rotation and without proper fertilization. The experiments conducted by the department have shown that the yield can be very greatly increased by rotation systems and by the use of fertilizers where the lands are deficient in any of the necessary elements, as they often are in nitrogen, potash, and phosphoric acid. In all sections the experiments have shown that great improvements can be made in the tobacco crop by careful selection. Tobacco is cross-fertilized by insects, so that in order to secure uniformity in product it is necessary to prevent insect visits to the flowers. In view of the fact that the tobacco is perfectly self-fertile, this is easily accomplished by bagging the flower stalks before the flowers open. In this way, by carefully selecting the mother plants, it is possible to produce improved strains of great uniformity, and as a few plants produce all the seed required for a large crop, the use of this bagging system, introduced by the department several years ago, has already resulted in the development of strains of superior quality and much higher yield.

The work of the department has also demonstrated that it is possible to separate the light from the heavy seed in order to produce greater uniformity. A simple device for this purpose has been patented by the department and is now in wide use among the tobacco growers.

Great improvements in the quality and quantity of the marketable crop have been secured by better methods of curing and fermentation. A discovery made by one of the department experts of the relation between nicotine and the quality of tobacco has shown that the sharp biting quality which the leaf often has is due to an excess of free nicotine, and that in the better types of tobacco, although the total nicotine may be equal to or higher than the biting types, it is combined with an organic acid, usually citric or malic. Spraying the leaves during fermentation with a dilute solution of these acids, sufficient to neutralize the free nicotine, greatly improves the quality of the fermented product in cases where the normal citric acid content of the leaf is not sufficiently high to accomplish this.

The production of wrapper and filler tobaccos has been rapidly extended of late years in Florida, Georgia, Alabama, and Texas. Many farmers have gone into the culture of this crop without due consideration of the difficulties involved. The result has been that in the last two years, especially, large quantities of low-grade leaf have been produced—due in part also to unfavorable seasons—and much of it still remains in the hands of the farmers, there being no sale except for the better qualities. This illustrates the danger of too rapidly expanding the culture of a crop requiring such skill and judgment as the production of tobacco of the higher grades.

The total acreage of tobacco in the United States has considerably decreased since 1903, the 1907 area being about 200,000 acres short of the acreage for 1903. The average yield per acre, however, has gradually increased, though the total production as the result of decreased acreage is slightly less than in former years. The average farm price per pound, however, has gradually increased. The domestic exports have remained fairly constant, while the imports of manufactured tobacco have slightly increased. Both the area and the yield in all our types of tobacco can be readily increased as fast as the demand warrants and the price is remunerative.

Hops.—Brief attention should be called to hop production. The United States is becoming an important hop-producing country, though the quality of American hops is somewhat inferior in the estimation of some to certain types produced in Europe. Little attention has been given to the improvement of varieties, and preliminary studies indicate that great improvements can easily be accomplished in quality and in yield. The quantity produced in the United States ranges between 40,000,000 and 60,000,000 pounds annually. The export trade in hops is gradually increasing, nearly 17,000,000 pounds having been exported in 1906. The imports of special qualities of hops, however, amount to between 6,000,000 and 10,000,000 pounds.

POTATOES.

Irish potatoes (*Solanum tuberosum*).—The species to which the potato belongs has been cultivated in the high plateaus of Peru for probably two thousand years or more. It was carried from Peru to Spain, from which country it was probably introduced into North America. Since the discovery of America the potato has rapidly spread into all countries to which it is adapted, especially the cooler temperate regions, until it has become one of the most extensively grown and most valuable food crops of the world, with an annual yield of approximately 5,000,000,000 bushels. According to Fraser,[a] 1 acre of potatoes frequently furnishes as much human food as 10 acres of wheat. Wherever wheat is a precarious crop, as in northern Europe, potato growing has been extensively developed. Yields of 1,000 to 1,200 bushels of potatoes per acre, containing 10,000 pounds of starch, are on record. The average yield for Russia is about 95 bushels per acre; Germany, about 200 bushels; England, 230 bushels; Ireland, 150 bushels. The United States produces approximately 3,000,000 acres per annum, with an average yield for the past ten years of 86 bushels annually. The average yield for 1904 was 110.4 bushels per acre and for 1906, 102.2 bushels. The average yield fell down to 65 bushels in 1901, the crop being badly affected by drought in that year in several of the heavy-producing States. The highest average yields are secured in the New England States and in the irrigated portions of the Rocky Mountain and Pacific Coast States.

The potato does best on a deep, mellow, easily worked loam containing a rather high humus content. Ten or fifteen tons of barnyard manure per acre, plowed under in the fall, or cover crops of buckwheat, clover, hairy vetch, or other similar green crop, put the soil into excellent condition for potatoes. However, in all cases the organic matter should be in a thoroughly decayed state before the crop is planted. In the case of old sods there is danger from grubs and wireworms, so that the cover crop for potatoes should not be

[a] S. Fraser; Cyclopedia of American Agriculture, 1907, vol. 2, p. 520.

more than one or two years old. Where buckwheat does well it is considered an especially good cover crop for potatoes, as it leaves the soil in excellent tilth, and remarkably smooth tubers are produced following this crop. Some of the finest potato soils in the United States are the reclaimed tule peat lands of California.

In all the potato districts there is a tendency to grow the crop year after year on the same soil, with the result not only of humus destruction but the accumulation of several serious diseases of the potato, especially the wilt disease, the bacterial disease, and in the Northeastern States the potato rot and scab. The latter disease is especially caused by the alkalinity of the soil, developing best in soils of an alkaline reaction. The yields during some years and in some sections are often very greatly reduced by these diseases. When the soils become thoroughly infected with these parasites it is difficult to eradicate them, as many of them live for long periods saprophytically. Some progress has been made in selecting varieties resistant to these diseases, but so far the work has had very little effect on the commercial production on account of the fact that no varieties have been developed which have a good market demand and which are at the same time disease resistant.

In the North Central States the so-called early and late blights, due to fungi attacking the leaves, cause in years favorable to these diseases very great loss, but it has been shown that by spraying the crop with Bordeaux mixture it is possible to reduce these losses to a negligible quantity. However, spraying methods are practiced only by the more progressive growers. The same treatment prevents the injury from flea beetles, which otherwise do great damage to the crop, and the use of Paris green with the Bordeaux mixture also prevents the attack of the potato bug, which also does immense damage to crops not protected.

Potato culture is considerably practiced in the South for early markets by importing seed tubers from the North. Southern-grown potatoes are not satisfactory for seed, as the crop is not adapted to hot climates. It is believed, however, that strains could be adapted for culture in the South by the development of seedlings in that region and possibly by hybridizing the *Solanum tuberosum* with some of the other tuber-producing species, as *S. maglia*, which is a native in the coasts of Chile, or *S. commersonii*, a native in Uruguay and Argentina, in rocky and arid situations at low levels. Of the 1,000 species of the genus *Solanum* in many parts of the world, there are about 20 species which bear tubers. It is possible that by combining these with the valuable qualities of the species at present in cultivation its range and adaptation can be very greatly increased, and possibly the food value, especially the nitrogen content of the tubers, can also be improved by this process.

Until within recent years most of the culture of potatoes has been carried on by hand, but potato planters and diggers have now been adapted to this crop, thus greatly decreasing the cost of production.

Sweet potatoes.—The sweet potato, *Ipomoea batatas*, is a member of the morning-glory family and is one of our important vegetable crops of the Southern States. The species from which the sweet potato developed, while not now positively known in the wild state, probably originated in Central or South America, possibly in Peru, where there are records of its ancient existence. It is, therefore, essentially an American crop, but, like the ordinary potato, its culture has extended into many other countries. Related species occur in China and eastern Asia, and its cultivation there may have been coincident with that in South America.

The commercial production of sweet potatoes in the United States extends as far north as middle New Jersey and as far west as Kansas. It is grown extensively under irrigation in southern California. According to the Twelfth Census, the sweet potato is, next to the Irish potato, the most extensively grown vegetable in the United States, and was reported on more than 1,000,000 farms. The acreage, including that of yams, was 537,447, and the value of the crop in 1899 was nearly $20,000,000. The largest production is in North Carolina, Georgia, Virginia, Alabama, and South Carolina.

The sweet potato requires a warm, sandy, well-drained soil, and responds well to fertilizers and manures. A high humus content is essential, as the crop suffers quickly from drought. Crimson clover sod is especially valuable if plowed under while the clover is young. With heavy manuring and fertilizing, sweet potatoes may be grown upon the same land for several years, and this practice is often followed. Several serious diseases, however, result from this practice, especially the so-called black-rot of the roots. The disease does not do so much damage in the field, but when the land becomes infected its presence in the stored potatoes causes them to rot, and in this way it is very injurious. As a rule, however, sweet potatoes are remarkably free from enemies.

The yield per acre depends largely upon the favorableness of the soil, fertilization, and the care and culture of the crop. The yield per acre in the United States averages about 83 bushels for white farmers and about 67 bushels for colored farmers. Yields of three or four times this amount, however, are easily secured where conditions are favorable. The crop is one of increasing importance and is susceptible of great improvement, not only in the matter of varieties but in cultural methods.

The food value of the sweet potato is higher than that of the Irish potato, and its use for feeding to stock is increasing. The principal use of the sweet potato is for the table, and the demand is rapidly growing, especially on the cotton and tobacco lands in rotation with corn, peanuts, and grass.

CASSAVA.

This crop, belonging to the same family as the castor bean, is widely cultivated in the tropics and is probably native to Brazil. The roots produce large quantities of starch as well as considerable nitrogenous matter, making a very valuable food for man and animals.

The culture of the crop has been tried for some years in Florida, but, owing to the fact that the plants had to be propagated from cuttings, which were difficult to produce in a healthy condition, the yield of good plants per acre has been so small as to make the industry unprofitable. The difficulty of propagating from canes led the Department of Agriculture to experiment in the production of a strain of cassava that could be propagated from seeds sown annually. Most of the varieties do not come true to seed, and the results are so variable when the seed is planted that heretofore it has not been adopted as a method of propagation. The department has, however, as a result of several years' selection secured strains which produce readily and uniformly from seed, yielding from 8 to 10 tons of roots per acre. It is believed that the use of these new varieties will make this one of the most important root crops of Florida and possibly of other areas along the Gulf coast. It is valuable not only for stock and as tapioca, for human food, but for starch, glucose, and alcohol manufacture. It is believed that as a source of denatured alcohol it will be cheaper than any other starch-producing plant.

VEGETABLES.

It will not be possible in this paper to discuss individually the very great number of crops grown as vegetables for market. Market gardening in the neighborhood of the large cities has developed at a rapid rate in the past ten years. Over 2,000,000 acres are reported in the last census as having been devoted to vegetable crops on over 615,000 farms. Twenty-five per cent of these farms derive their principal income from vegetables. These crops are produced in the neighborhood of the large markets under very intensive culture, the most careful attention being given to every detail of cultivation, both in the matter of the selection of soils, their fertilization, the selection of seed, and the marketing of the crops. With the increased facilities in transportation, and the great growth of the canning industry, the areas available for market gardening and truck crop growing have been greatly increased in recent years.

FRUITS.

Next to vegetables and flowers and products under glass, the most careful attention has been given in the United States to the production of fruits. According to the last census, the total production for the United States amounted to over $131,423,000. Of this, $83,751,040 represented orchard fruits, a little over $14,000,000 grapes, over $25,000,000 small fruits, and about $8,500,000 subtropical fruits.

Orchard fruits.—Of the orchard fruits, 55 per cent was apples, 27.2 per cent peaches and nectarines, 4.8 per cent pears, 8.4 per cent plums and prunes, 3.2 per cent cherries, and 1.4 per cent apricots. According to the census reports, the apple increased its proportion of the total production of orchard fruits from 76.3 per cent in 1889 to 82.8 per cent in 1899; the pear from 1.6 per cent to 3.1 per cent; the plum from 1.4 to 4.1 per cent; cherries, 0.8 to 1.4 per cent; apricots, 0.5 to 1.3 per cent. Peaches, owing to a complete failure in many sections, decreased from 19.4 per cent to 7.3 per cent. The States which took the lead in 1899 in the value of their orchard products were: California, over $14,500,000; New York, over $10,500,000; Pennsylvania, nearly $8,000,000; Ohio, over $6,000,000; Illinois, nearly $4,000,000; Michigan, nearly $4,000,000; Indiana, over $3,000,000; Missouri, nearly $3,000,000; Virginia, over $2,500,000; New Jersey, over $2,500,000.

These States reported an aggregate value of orchard fruits of over $58,000,000, or 69.3 per cent of the total value of all orchard fruits in the country.

There is an immense number of varieties of all these fruits grown in the United States, some of them introduced from foreign countries and others produced as chance seedlings from time to time here. Our finest apples have largely been the result of seedlings discovered from time to time by different growers. In the early days of the country, before the development of nurseries, many of the orchard trees were raised from seed, and most of our valuable varieties originated during this period of seedling orchards. Later, with the development of nurseries and the bud propagation of the more valuable sorts, the development of seedling varieties gradually dropped into the background. In recent years, however, as the demand for better acclimatized sorts has developed, more attention has been given to the production of seedlings. This is especially true in the northern Mississippi Valley region, where the very cold winters and hot dry summers are very destructive to the tenderer orchard fruits.

A number of serious disease and insect pests attack all our orchard fruits, in the case of the apple and pear especially the bacterial blight and the codling moth. The bacterial blight is very difficult to control and has destroyed the finer varieties of pear in most parts of the United States. Until recently the great Bartlett pear orchards of California were comparatively free from this disease, but within the past few years it has been introduced and has destroyed more than $5,000,000 worth of orchards, representing about one-third of the pear industry of that region. Methods for controlling the disease have been worked out, but they are not yet entirely satisfactory.

The various leaf diseases and the diseases attacking the fruit can be controlled by spraying, and progressive orchardists now follow this practice.

Peaches.—In the case of peaches the principal disease in California is a twig and limb blight, which practically destroyed the industry in many sections until the Department of Agriculture demonstrated that the disease could be controlled by spraying with Bordeaux mixture. In the Eastern and Southern States the principal disease of the peach is the yellows. In Michigan and New York a new disease known as "little peach" has appeared, and in all these sections, especially in the South, peach rot, caused by a fungus attacking the fruit, is very destructive. The first two diseases can be controlled by the eradication method; that is, the immediate destruction of the diseased trees and replanting. The latter disease heretofore has not been controllable, owing to the fact that the copper-spraying mixtures have been destructive to peach foliage. The recent discovery by one of the department experts that the peach rots could be controlled by self-boiled lime-sulphur mixture has marked the beginning of a new era in peach culture.

One of the principal difficulties with our cultivated varieties of peaches is probably that they are not perfectly adapted to the climatic conditions of our Eastern and Southern States. Whether improvements can be made along the line of better adaptation of varieties is still a question so far as peaches are concerned. A southwestern species closely related to the cultivated peach may possibly be of some value in this connection.

Plums.—The blood of our native plums has largely entered into the varieties adapted for culture in the various sections of the United States. The European plums and even the Japanese varieties have not proved to be well adapted to our climatic conditions and are not resistant to the diseases and insects prevalent here. Hybrids between many of these finer-fruited sorts and our native plums, however, combine the good qualities of both. There are over 200 horticultural varieties of native plums now described. While they are now largely cultivated, it is probable that the better hybrid sorts will eventually take their place.

Apples.—The apple, which appears to be fairly well adapted to our Northeastern States, is not well adapted to the severe climatic conditions of the upper Mississippi and Missouri valleys. Some seedling varieties have been developed which are superior to the ordinary cultivated sorts, but the final development of varieties adapted to this region of extremes of climate will undoubtedly come through the introduction of the blood of the native crab of that region. If the resistance, vigor, and adaptability of this native species can be combined with the good fruit qualities of the ordinary apple, an ideal variety will be produced.

Small fruits.—The total acreage of small fruits reported in the last census was 304,029 acres, valued at $25,030,877, and may fairly represent the status of this class of crops. From the commercial standpoint, the small fruits are usually classed with vegetables and truck crops and are cultivated for special markets or for canning and drying. The small amounts usually grown on most farms and often on city lots for home use are usually not reported for census enumeration, but in the aggregate amount possibly to as much as the reported area.

The small fruits of greatest importance are the strawberries, raspberries, blackberries, currants, gooseberries, and cranberries. There are a very large number of excellent varieties of all these fruits, developed largely from our native wild species. Introduced varieties were early found not to be well adapted to our conditions and were seriously affected by diseases occurring on our wild species, but to which our native species were resistant. However, in the improvement of varieties our native and introduced species have often been hybridized and the good qualities of both sorts thus combined. The strawberry, our most important small fruit, is an exception to this rule, as the species giving rise to our cultivated strains is a native of Chile, although there are a large number of good native varieties. In all the small fruits, however, there is the greatest opportunity for improvement, especially along the line of adaptation to special conditions and uses. With the increasing demands for this class of fruits improvements are gradually taking place. We have the foundation of our native species for almost unlimited development.

Grapes.—With the exception of California, the grape industry of the United States is based on our native species, the improved varieties being largely accidental seedlings. The Old Cape or Alexander grape was found wild in the woods of Pennsylvania; the Catawba was found in the woods of South Carolina; the Concord was a chance seedling in a Massachusetts garden, probably from the wild fox grape; the Worden was raised from a seed of Concord; the Delaware was probably a chance cross between a native species and a European variety, as both existed where the Delaware originated. Some very fine varieties, like the Brighton, were the result of artificial crosses. Only a very little has been done in the production of varieties for special purposes and in their general improvement. The quality of

European grapes is far superior to that of the American varieties, but the former are not adapted to our climate or resistant to our grape diseases, especially the phylloxera and black and brown rots. If the vigor and disease resistance of our native species can be bred into some of the finer European sorts, it would mean a new era for the grape culture of the Southern, Eastern, and Middle States.

In California the European varieties do fairly well, and a large industry in their culture has developed. Many of the varieties, however, are not perfectly adapted to California conditions, and the introduction of some American vigor has already been found necessary in order to obtain resistance to phylloxera, which has now gained a foothold in California, and to the California vine disease, which is very destructive to the tender European sorts.

California has over 90,500,000 vines, producing over 721,000,000 pounds of grapes, valued at over $5,500,000. These are largely of the European types. New York has over 29,500,000 vines, producing nearly 250,000,000 pounds of fruit, valued at nearly $3,000,000. Ohio has about half as much as New York, and Pennsylvania, Michigan, Illinois, Indiana, Kansas, Missouri, Georgia, Iowa, and Oklahoma have from 3,000,000 to 5,000,000 vines each.

There is a decided tendency to the overproduction of the American varieties. Even in the culture of the more resistant strains careful spraying is necessary in order to control the black and brown rots.

Subtropical fruits.—Of the subtropical fruits the principal ones are the orange, lemon, banana, pineapple, lime, citron, pomelo, guava, olive, etc. Of these the largest industry is in orange culture, California leading with about 5,500,000 trees, Florida with 2,500,000, Louisiana with 141,116, Arizona with 48,570, and smaller numbers in Texas, Mississippi, Alabama, and a few other States.

The principal lemon industry is in California, Florida, Arizona, and to a small extent in other States. The other citrus fruits are also grown in the same States.

The principal difficulty with the citrus industry arises from the effect of cold waves and heavy frosts striking the orchards during the growing season. The industry has been several times nearly destroyed in Florida and the Gulf States from this cause and has suffered seriously in some localities in California. Most of the citrus fruits cultivated in the United States are the results of what might be considered chance introductions and chance seedlings. There are many much more cold-resistant varieties of oranges in India, China, and Japan, which would doubtless prove valuable for northern Florida and the Gulf States. These introductions will be made by the Department of Agriculture. Another recourse is the crossing of the tenderer fine-fruited sorts with the cold-resistant *Citrus trifoliata*, which grows as far north as Philadelphia. From the many results of such crosses it is evident that oranges of much greater cold-resisting power can be developed. A large number of new types of citrus fruits have thus been secured, some of which are seedless and very juicy, some very sour, some moderately sour, and some fairly sweet. These are of first generation hybrids, however, and it is from the second generation that the larger number of intermediate sorts will develop. Varieties of citrus fruits for home use will undoubtedly result from such breeding work adapted for growth throughout the cotton States and the Southwest.

In the hotter sections of the Southwest where irrigation is practiced there are many areas of soil too alkaline for ordinary crops which are adapted to the date palm. About 50 varieties of the finer strains of dates have been introduced from the Old World and are found to give excellent results in this southwestern region. A profitable fruit industry can therefore be built up in soils and climate not adapted to other fruits. In the drier sections of the Southwest the dry-land olive is proving successful, and this valuable source of olive oil can undoubtedly be cultivated over large areas in Arizona and California, and possibly in New Mexico.

The pistache nut, also adapted to these dry areas, has been introduced and is proving well adapted to the region.

Similar improvements have been undertaken with the lime, the lemon, the grape fruit, the tangerine, and other species. In the case of the pineapple more than 200 new seedling varieties have been developed, some of which are far superior to any varieties now grown in the United States.

Besides these fruits there are many other tropical and subtropical fruits which are being tested in these regions and can be developed into industries of considerable importance as soon as there is demand for them.

NUTS.

Almonds.—The cultivation of almonds has developed to a considerable extent in California and Arizona, principally, however, in the former State, where over 1,500,000 trees are grown, producing nearly 7,000,000 pounds of nuts.

Cocoanuts.—Cocoanuts are produced in considerable numbers in Florida, approximately 50,000 trees being recorded in that State in the last census. This nut, however, is far more important in Cuba, Porto Rico, and the Philippines. It has recently been attacked by a serious disease, destroying in a short time many of the trees. Unless some means of control is discovered it is feared that the industry will be destroyed in all these places. The disease has not yet reached Florida or Porto Rico.

Pecans.—The pecan hickory is native in the Southern Central States, and many valuable seedling varieties are known. The nut has been planted in orchards in recent years and large quantities are thus produced. The finer varieties are now being selected and propagated by budding and grafting, so that the nut can now be said to be practically domesticated and in the process of improvement. Something over 3,000,000 pounds were produced during the last census year, about 56 per cent of which was grown in Texas. The pecan is susceptible of great improvement, and the extension of this nut industry is certain to be very great, provided the diseases which attack the cultivated orchards can be controlled.

English walnuts.—The Persian or English walnuts are cultivated to a considerable extent in southern California, where there are now nearly a million trees, producing something over 10,000,000 pounds of nuts. Not much attention has been given to varieties, so that the orchards are considerably mixed. A serious disease caused by bacteria has greatly reduced the yield, but it has been discovered that certain varieties are resistant, and it is probable that many of the orchards will be worked over to these resistant strains.

Very little attention has been given to the improvement of the great number of native nuts growing in various sections of the United States. With the increasing importance of this class of fruits it is probable that the native species will be domesticated and greatly improved in the near future.

SUMMARY.

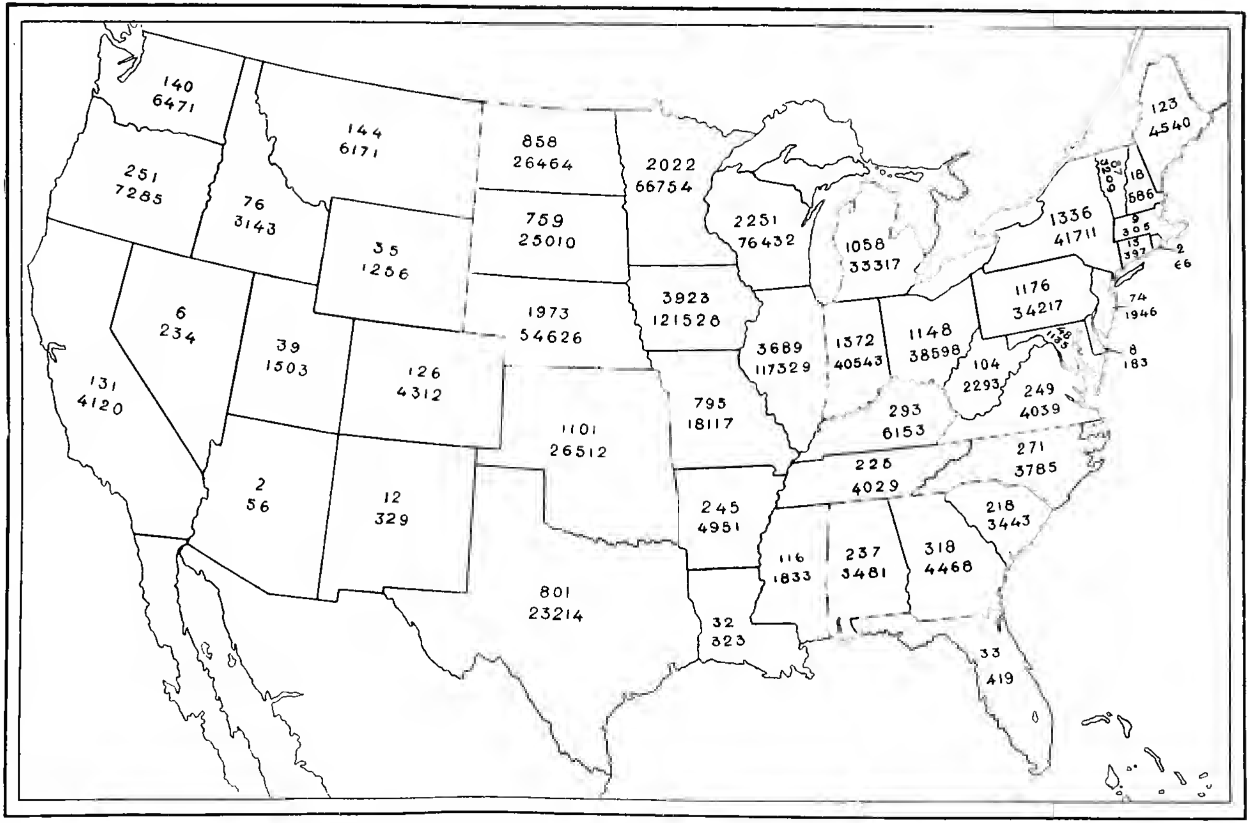
I have now presented very briefly some of the principal facts regarding our important cultivated and native plants, and have shown that we have in all our plant resources a large number of extremely valuable varieties and sorts of local adaptation simply waiting to be utilized. Our agriculture and horticulture have been extremely primitive in the attention which has been given to seed selection, the improvement of varieties, and their adaptation to special uses. This, of course, has been the result of the rapidly expanding areas brought under cultivation and the general promiscuous and careless testing of varieties. In the past the great market demands for staple crops have given little consideration to anything but the most general qualities. Improved transportation methods have brought practically the whole world into competition, so that the cheapest and most extensive methods have necessarily prevailed. As population increases and territorial expansion decreases, the demand for more intensive methods becomes greater and more attention can be given to the improvement of cultural methods. The first step in this direction will certainly be the better utilization of our enormous plant resources.

It has been shown that by careful selection of the best individual plants, and propagating from these, the yield of all our important staple crops could easily be doubled. The means for accomplishing this already exist in our fields and gardens. For still greater improvement we can draw on cultivated and wild plants throughout the world. With the exception of the absolutely arid sections of the United States, where no rainfall or other source of water is available, there is not a foot of ground from which valuable crops can not be secured or developed, and these include grain, forage, and fruits.

Besides the great gains which can be secured by the selection and improvement of varieties of crops, the improvements in cultural methods also offer opportunities for great increase in quantity, quality, and certainty of yield. The great mass of our farmers have been as careless in their methods of agricultural production as they have in their selection of varieties. While there has been tremendous waste in following such methods, due to the rapid expansion, the close competition, and the small margin of profit, the conditions have nevertheless been the cause of the development of some of our most important mechanical methods. It has been necessary to cultivate large areas with a small amount of labor, which has led to the wonderful development of mechanical methods and improved machinery which has characterized American agriculture.

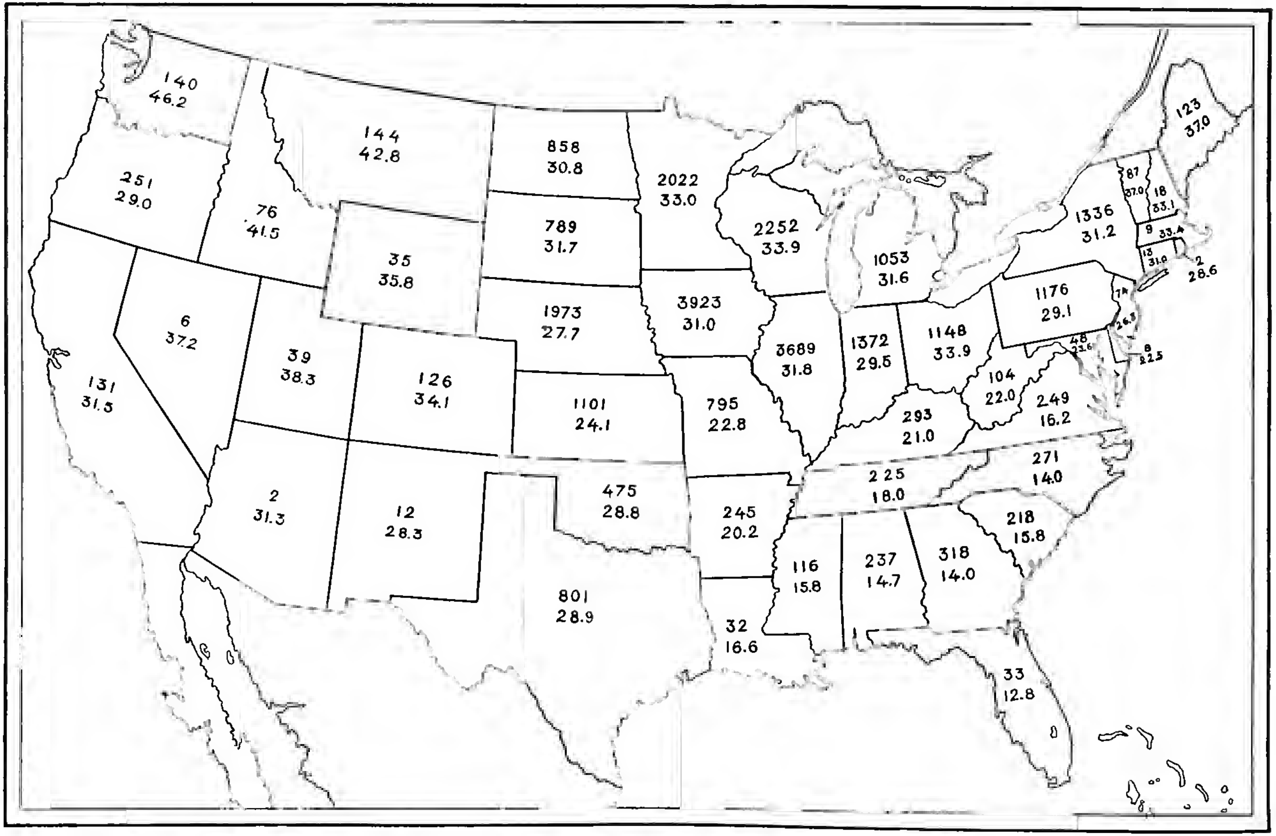
Along with the general careless methods, little attention has been given as a rule to the conservation of soil fertility. This matter has been referred to briefly in the discussion of the various crops and will not be entered into further in this paper, as it is covered by the work of another bureau. Although the larger part of the product of plant growth is taken directly or indirectly from the air, nevertheless a small but essential part comes from the soil, and it is absolutely necessary, in order to maintain the soil in a highly productive condition, to keep in it a readily available supply of the essential nutrients, especially nitrogen, phosphoric acid, and potash. The physical condition of the soil, its water-holding capacity, and its ability to absorb oxygen are controlled in a large measure by the organic matter which it contains. A high humus content is essential to a good soil. More than any other factor influencing the fertility and crop-producing power is the organic life of the soil, especially the bacteria and fungi and low organisms of this class inhabiting it. The control of the nature and quantity of these organisms present is soon to become one of the most important factors in agricultural production.

The accumulation in the soil of organisms deleterious to crop growth, resulting from continued culture to a single crop, is one of the most prolific causes of the deterioration in crop-producing power, as has been pointed out in the case of a number of our most important crops. Besides the development of resistant crops, the most important procedure will be in the adoption of crop-rotation systems which prevent the accumulation of these parasites and which enable the producer to make the proper return to the soil, by fertilization and other means, of some of the elements taken from it.



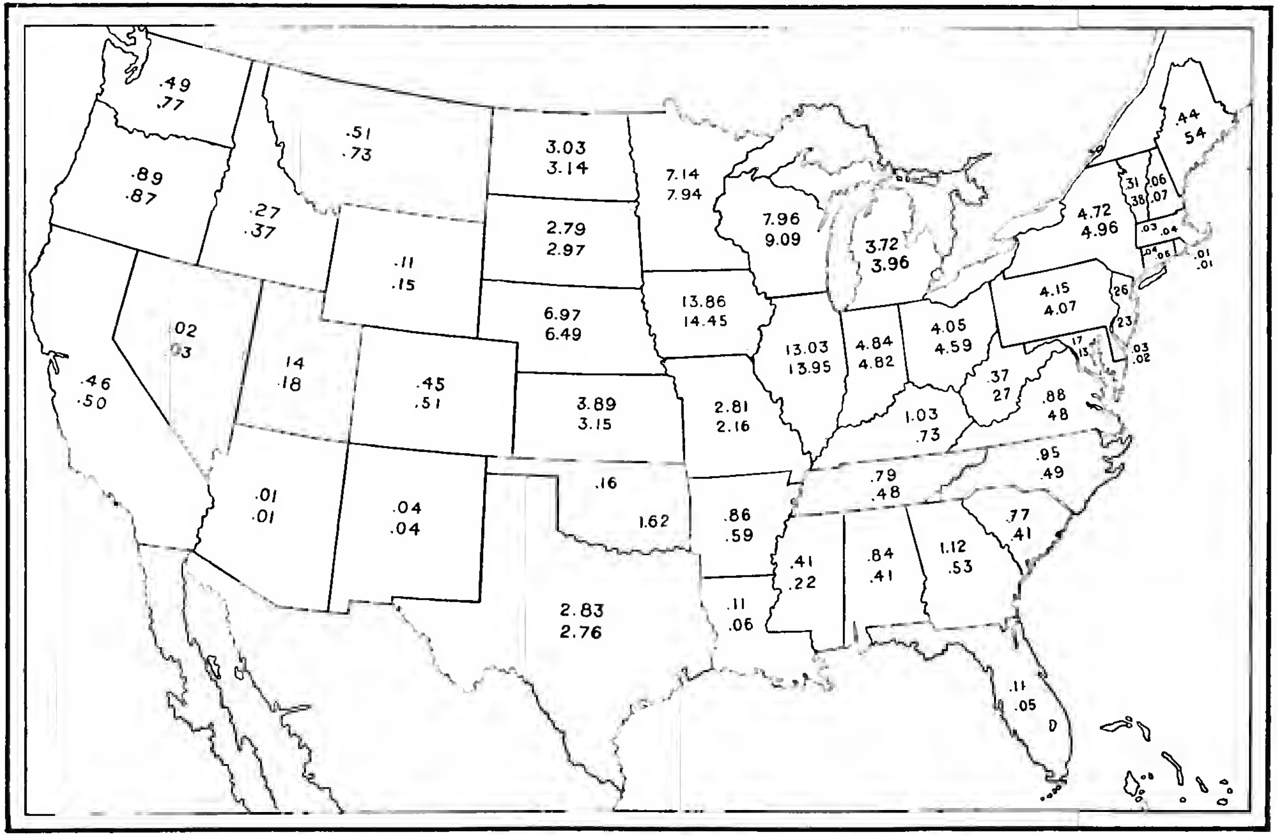
MAP NO. 1.—OAT CROP OF THE UNITED STATES, 1898–1907.

Upper figures show average annual acreage in thousands of acres. Lower figures show



MAP NO. 2.—OAT CROP OF THE UNITED STATES, 1898–1907.

Upper figures show annual acreage in thousands of acres. Lower figures show average yield per acre.



MAP NO. 3.—OAT CROP OF THE UNITED STATES, 1898-1907.

Upper figures show percentage of average annual acreage. Lower figures show percentage of average annual production.

THE OAT CROP.

By C. W. WARBURTON,
Bureau of Plant Industry, United States Department of Agriculture.

IMPORTANCE OF THE CROP.

Oats rank fifth among the farm crops of the United States in importance and value, being exceeded only by corn, hay, cotton, and wheat. The average area devoted to the production of this crop in the ten years from 1898 to 1907 has been 28,300,000 acres, while the average annual production has amounted to 841,000,000 bushels. The average annual farm value for the same period, as estimated by the Bureau of Statistics of this department, has been $265,596,000, or $9.38 to the acre. This is slightly less than the acre value of the wheat crop, $9.62, and about a dollar less than that of corn, $10.40.

The accompanying map (No. 1) shows the average annual acreage in each State for the past ten years and the average total production of each State. Map No. 2 also shows the annual acreage, with the average yield to the acre, while map No. 3 shows each State's proportion of the annual acreage and production. This last is of particular interest, as it shows the relation between acreage and production in the various States. Thus Iowa, the leading State, produces 14.45 per cent of the total crop on 13.86 per cent of the acreage, and Illinois produces nearly 14 per cent of the crop on slightly more than 13 per cent of the acreage. As extremes, Washington and Georgia may be cited, the latter producing but 0.53 per cent of the total crop on 1.12 per cent of the acreage, while the former shows 0.77 per cent on but 0.49 per cent of the total area.

REGION OF GREATEST PRODUCTION.

The production of oats is greatest in the northern Mississippi Valley, in the northern part of the region generally known as the corn belt, and in the States lying just to the north of that belt. The "oat belt" might be said to include Iowa, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, and Nebraska. In these 7 States are included 54.78 per cent of the total acreage and 58.03 per cent of the production. If the crop of Michigan, Ohio, and Indiana is added to that of the 7 States just mentioned, these figures increase relatively to 67.91 per cent and 71.4 per cent. While the crop is thus centralized it is comparatively cosmopolitan in its nature, for it is grown in every State and Territory, and in only two, Rhode Island and Arizona, is the annual crop less than 100,000 bushels, while corn falls below that figure in Montana, Wyoming, and Nevada. In 15 States, notably in New York, Wisconsin, and Minnesota, the oat crop exceeds the corn crop in value.

NEED FOR IMPROVEMENT.

While the foregoing figures show that the oat crop is very largely to be reckoned with in our farm economy, yet the partial failures in the two seasons just past, 1907 and 1908, in which unfavorable weather conditions, insects, and diseases combined to reduce the production to a point well below the ten-year average, indicate the need of a thorough study of varieties and their adaptation, methods of combating insect and fungous pests, and of seeding, fertilizing, and harvesting the crop.

VARIETAL ZONES.

No very definite divisons can be made to show the adaptability of varieties or of classes of varieties, but, roughly speaking, the States may be grouped into three zones, the southern one including Delaware, Maryland, West Virginia, Kentucky, Missouri, Kansas, and the States to the south, and extending westward through New Mexico and Arizona to California; a central belt including New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Iowa, and Nebraska; and a northern one embracing New England, New York, Michigan, Wisconsin, Minnesota, the Dakotas, the Intermountain States, and the States of the Pacific Northwest. This division is inaccurate and far from satisfactory, but in general the best producing varieties or types are similar within these three divisions.

THE SOUTHERN DIVISION.

The first, or southern, division includes about 20 per cent of the total annual acreage of oats, but produces only 15 per cent of the crop. The varieties most largely grown are Rustproof, Virginia Gray, and Burt. Rustproof, often called "Texas Red" or "Texas Rustproof," is the typical and parent variety of the Rustproof group, which includes Appler, Lawson, and Culberson. This group, as usually grown, is a mixture in varying proportions of at least three varieties, the typical large-grained red oat of the true Rustproof variety, a strain with medium-sized black grains, and one with small white ones. It is probable that the red grain is the most desirable type, though very good results have been secured from the small white strain when separated from the mixture. The ordinary red type is of medium height, straw usually strong, and the grain large and reddish or yellowish brown in color. Practically all of the berries are bearded, the beards, particularly on the larger grain, being large and long. The larger grain is also provided with a number of long, bristly hairs at the base, a characteristic which distinguishes this group from the other varieties commonly grown in the South, in which the bristles are either entirely wanting, occur on only a few of the spikelets, or are much shorter than on Rustproof. The varieties of this group are, as the name indicates, resistant to rust, and are generally the most productive and satisfactory for growing in the section under discussion. They may be sown in the South either in fall or spring—in fact, at any time from September to March. In the northern part of the belt, late winter or spring sowing is generally advisable, though the fall-sown crop is usually more productive when it survives the winter.

Virginia Gray or Winter Turf is a taller, more slender variety than Rustproof, adapted to fall or early winter sowing in this region. It is rather hardier than Rustproof and is grown largely in Virginia and North Carolina, and to some extent in Kentucky, Tennessee, and the other Southern States. It is not usually successful when sown in the spring. The grain is of medium size, usually not bearded, gray or light grayish yellow. The two grains of the spikelet separate readily in thrashing, while in Rustproof they are usually quite persistent. This variety is of value where Rustproof will not withstand the winter, or where the production of hay or straw is more important than that of grain.

Burt is the only strictly spring variety of oats generally grown in the South. At present it can hardly be considered of importance outside of Kentucky and Tennessee, though it is grown to some extent in the higher portions of the other Southeastern States. This variety, sometimes known as "Ninety-Day" or "May," has more slender, lighter-colored grains than Rustproof, and the spikelets are usually without the basal hairs. It ripens earlier than Rustproof and in some sections is more productive. On account of its earliness it frequently escapes injury from fungous diseases which attack other spring-sown varieties. This variety, as well as Virginia Gray, is quite pure as ordinarily grown.

The greatest need for work on oats in the South, so far as the variety question is concerned, is the production of pure strains of Rustproof, which are winter hardy and highly productive. This should be comparatively easy to accomplish in a few years by careful selection. Other means of increasing the acre yield, and so increasing the net return, are good preparation of the seed bed, fertilization, and early seeding.

The oat crop in the South is frequently put in with little preparation, the seed sometimes being sown broadcast on cornstalk or other land and covered with a cultivator or disk harrow. Where a grain drill is available, however, it is more frequently used than is the case in the corn belt. Sowing with a grain drill not only aids in securing a uniform stand by distributing the seed evenly and covering it all to the same depth, but, in the case of fall-sown grain, the furrows left by the drill serve as a protection from the heaving caused by the alternate freezing and thawing of winter and early spring. In some sections of the South, particularly in Georgia, what is known as the "open-furrow" method of seeding is quite common. A planter similar to a cotton planter is used, the seed being drilled in the bottom of an open furrow. This furrow is left open through the winter, except as it is closed naturally by the washing of the banks and by the action of frost. This method obviates in a large measure the danger of winter damage, but is slow and expensive, as only one row can be sown at a time. A machine on the order of a grain drill, which sows several rows at once but leaves the ground more ridged than the ordinary type of that tool, is desirable for the winter oat region.

In the South, as in the North, the oat crop is ordinarily grown on the poorest land. While it is true that oats will produce relatively more on poor land than will other grain crops, yet the crop responds so readily to good treatment and fertilizers that the extra expense is justified. The use of fresh manure is not advisable as it is likely to cause a rank growth of straw, liable to lodge, at the expense of grain production. Well-rolled manure and complete fertilizers, particularly those rich in potash and phosphorus, are productive of the best results, though nitrogenous fertilizers, especially those in the form of green manures, are decidedly beneficial.

The winter oat crop is ordinarily sown in late October or November, whereas careful tests show that larger and more certain crops can be secured by seeding in September or early October. If spring seeding is necessary, it should be done as early as possible—during February in the extreme south and in March in the northern part of this belt. Spring seeding is not to be recommended, however, where there is any possibility of securing a stand from fall sowing.

The advantage of early fall seeding over later sowing is obvious. The young plants become well established before cold weather, and the growth of both top and root is often sufficient to prevent winter injury which would be serious in the late sown fields. Fall or very early spring seeding is to be recommended over late spring seeding, as it hastens maturity, i. e., the crop ripens in time to avoid much damage from unfavorable weather conditions and fungous diseases.

THE CENTRAL DIVISION.

In the central belt, which includes 47 per cent of the crop area and 48.5 per cent of the total production, oats, while largely grown, can not be considered profitable. A recent estimate by Prof. A. N. Hume, of the Illinois Experiment Station, shows that the average crop of oats in that State, 33 bushels, is produced at a loss of $3.32 per acre. However, the oat crop is a very necessary one in the common systems of rotation used in the corn belt, and is not to be discarded on the showing just quoted. Then, too, the best farmers secure yields much better than the state average, and the price, at least in recent years, is considerably higher than the 26 cents per bushel used in this calculation.

The varieties of oats grown in the central belt are too numerous for extended mention, but may be roughly divided into the small, early, yellow varieties, with rather light, slender straw, small, slender, white or yellow grain, maturing in ninety to one hundred days from sowing, and the large, medium to late varieties, taller and more rank growing with medium to large, usually white grain, maturing in one hundred to one hundred and twenty days. The latter group may be further divided into the Potato and Welcome groups, the former with short, plump grains, and the latter with longer, more pointed ones. In the first class may be included Alaska, Early Champion, Sixty-Day, and Kherson, the two latter having been imported from southern Russia about ten years ago. In the Welcome group may be included such well-known varieties as American Banner, Clydesdale, Lincoln, Silvermine, and Welcome, while in the Potato group Early Siberian, Green Mountain, Probsteier, White Schoenen, and Wideawake are to be found. The first-named group, though perhaps occupying the smallest acreage, is probably the most reliable, on account of its earliness, which enables it to escape unfavorable weather conditions and resultant attacks of fungous diseases. The chief objections to the varieties of this class are the small size of the grains and, in the case of Sixty-Day and Kherson, the yellow color. In tests at the Illinois, Iowa, and Nebraska stations, however, these two varieties have in recent years been most reliable. Early Champion is specially liable to smut attacks, and should always be treated with some one of the well-known smut preventives.

Of the Welcome group, Silvermine is perhaps the best known and most widely popular variety. The varieties of this group, however, frequently mature too late for the best results, as when sown around April 1, their ripening period, during the first two weeks of July and extending up to July 20 in the northern portion of this belt, is frequently decidedly unfavorable for the development of the oat crop. The oat crop is usually most satisfactory in cool, moist climates, and the heat of the July days in the corn belt is often disastrous, whether the weather is wet or dry. In a dry season, the grain ripens prematurely and is shriveled and light, and in a wet one, rust develops rapidly, with its resultant serious effect on the grain yield. The use of early varieties, which frequently mature before the weather conditions become unfavorable, is strongly to be recommended in the corn belt.

In the matter of soil preparation, the oat crop gets little attention. A circular of inquiry sent out to Iowa farmers showed that practically the entire oat crop was sown on corn ground, and more than 70 per cent of the farmers gave no previous preparation. The usual method is to sow the grain broadcast, then disk and harrow. In this manner it is put in at varying depths, germination extends over a considerable period, and the early growth of the crop is irregular. A considerable portion of the seed is covered so little or so much that it fails to germinate at all. Double disking and double harrowing of cornstalk land before seeding is strongly to be recommended, and sowing with a grain drill at a depth of 2 inches is desirable. In a test at the Iowa station, drilled seed yielded nearly 10 bushels more to the acre than broadcasted seed in 1907, a season of poor oat crops in that section.

Few fertilizer experiments with oats have been conducted in this section. The general belief that it is advisable to apply manure immediately preceding an oat crop is well founded, and the practice of manuring for corn and following the corn with oats is no doubt the best plan which can be devised. However, it may be well to apply some form of potash to the oat crop, for corn-belt soils are often low in available forms of this element and its addition might go far to solve the problem of weak straw and lodging.

THE NORTHERN DIVISION.

In the northern belt, where 33 per cent of the total oat acreage of the United States produced 36.5 per cent of the crop, the varieties ordinarily grown are of the same late maturing type frequently found in the section just discussed, though occasionally varieties of the early type are grown. In some sections "side" oats are the prevailing type. The varieties of this type are even later than the Potato oats. Owing to the fact that conditions here are usually more favorable during July than they are in the corn belt, late varieties are more reliable, though in some seasons they are not productive. At the Wisconsin station, Sixty-Day, a variety of the early type, and

Swedish Select, a Potato oat, are the highest yielding varieties. At the Minnesota station the leading varieties are Early Gothland, a rather early variety of the Silvermine type, and Imp. Ligowo, of the Potato type, while in South Dakota Sixty-Day and Swedish Select are prominent. In North Dakota side oats of the White Russian and Tartarian varieties are largely grown, though Sixty-Day has been a very satisfactory variety at the experiment station. In Montana and the Pacific Northwest the prevailing varieties are the late maturing Potato and side types.

General discussion of soil preparation, methods of seeding, and fertilization in the central district is also applicable here, though the more favorable weather conditions and better adapted varieties make the oat crop more commonly profitable than in the corn belt. Indeed, the oat crop is second only to wheat in this region and in some of the States is of even greater value than that grain.

The need of rotation and of cultivated crops is particularly great in some sections of this belt. In portions of Minnesota, and throughout the Dakotas and the Northwestern States, continuous cropping to wheat, barley, flax, and oats has greatly decreased the fertility of the land and increased the growth of weeds. An increased proportion of grass land and cultivated crops will check the weed nuisance, and the fertility of the land may be restored by the use of clover and other green-manuring crops, and of manure. More live stock should be kept, and the acreage of small grain should be reduced. With proper handling 3 acres will produce as much wheat or oats as 4 do now, and the remaining one-fourth of the land may be devoted to forage and live stock without reducing the grain production.

SMUT TREATMENT.

It is probable that smut annually destroys from 3 to 5 per cent of the oat crop of the United States. In certain sections, and in years favorable to smut development, the loss is much greater. A conservative estimate of 4 per cent of the annual crop would mean a loss of 34,000,000 bushels on an average crop, or a money loss on the same basis of more than $10,000,000. In view of the ease and cheapness of preventive treatment, either with formalin solution or hot water, there is no reason why this annual loss could not be almost entirely avoided.

METHODS OF HARVESTING.

While the discussion thus far has been entirely concerned with the preparation of the soil and the sowing of the crop, there is need of more attention in many sections to the methods of harvesting, particularly with regard to stacking the grain.

When properly handled the grain goes through three "sweats" or ripening processes, each of which, under suitable conditions, improves the quality. The first is in the shock, the second in the stack, and the third in the bin after thrashing. The very common practice of thrashing from the shock, a practice seemingly increasing in vogue, does away with the second sweat, and at the same time greatly increases the possibility of deterioration in quality from weather damage. The increase of cost from stacking is usually much more than balanced by the increased value of the crop over that left in the shock until thrashed.

SUMMARY.

The oat crop, which ranks fifth in importance among our farm crops, is annually valued at about $265,000,000. More than one-half of the entire crop is produced in seven States in the upper Mississippi Valley.

While immensely valuable and a very necessary crop in rotations, oats are frequently produced at a very small profit or often at a loss.

There is great need of improvement in varieties, methods of soil preparation, seeding, and harvesting to obviate this loss.

The United States can be approximately divided into three varietal zones.

The typical varieties of the southern zone are Rustproof, Virginia Gray, and Dun. The crop can be increased in the South by the selection of high producing winter strains, particularly of Rustproof, by early seeding and by the liberal use of fertilizers.

The typical varieties of the central zone are Sixty-Day, Silvermine, and White Schoenen. In this section the use of the earliest varieties, better preparation of the soil, and drilling are suggested.

In the northern belt, the region of greatest production to the acre, Tartarian, Swedish Select, Progress, and Sixty-Day are typical varieties. Better yielding strains of these varieties, better preparation of the soil, and drilling will increase the yield. Preventive treatment is essential to prevent serious loss from smut. Stacking will ordinarily increase the quality of the grain, while thrashing from the shock greatly increases the possibility of injury from bad weather.

THE ORIGIN OF CULTIVATED PLANTS.

By Alphonse De Candolle.

SUMMARY AND CONCLUSION.

[The "Summary and Conclusion," Part III of "The Origin of Cultivated Plants," by Alphonse De Candolle, is here reprinted (with some slight modifications) for convenient reference in connection with the article entitled "Agricultural Production," by A. F. Woods.]

GENERAL TABLE OF SPECIES, WITH THEIR ORIGIN AND THE EPOCH OF THEIR EARLIEST CULTIVATION.

The following table includes a few species of which a detailed account has not been given, because their origin is well known and they are of little importance.

Explanation of the signs used in the table: (1) Annual; (2) biennial; 4, perennial; 5, small shrub; 6, shrub; 7, small tree; 8, tree. The letters indicate the certain or probable date of earliest cultivation. For the species of the Old World: A, a species cultivated for more than four thousand years (according to ancient historians, the monuments of ancient Egypt, Chinese works, and botanical and philological indications); B, cultivated for more than two thousand years (indicated in Theophrastus, found among lacustrine remains, or presenting various signs, such as possessing Hebrew or Sanskrit names); C, cultivated for less than two thousand years (mentioned by Dioscorides and not by Theophrastus, seen in the frescoes at Pompeii, introduced at a known date, etc.). For American species: D, cultivation very ancient in America (from its wide area and number of varieties); E, species cultivated before the discovery of America, without showing signs of a great antiquity of culture; F, species only cultivated since the discovery of America.

Species native to the Old World.

CULTIVATED FOR THE SUBTERRANEAN PARTS.

Name and duration.	Date.	Origin.
Radish=Raphanus sativus (1)	B.	Temperate Asia.[a]
Horse-radish=Cochlearia armoracia 4	C.	Eastern temperate Europe.
Turnip=Brassica rapa (2)	A.	Europe; western Siberia (?).
Rape=Brassica napus (2)	A.	Europe; western Siberia (?).
Carrot=Daucus carota (2)	B.	Europe; western temperate Asia (?).
Parsnip=Pastinaca sativa (2)	C.	Central and southern Europe.
Tuberous chervil=Chærophyllum bulbosum (2)	C.	Central Europe; Caucasus.
Skirret=Sium sisarum 4	C.	Altaic Siberia; northern Persia.
Madder=Rubia tinctorum 4	B.	Western temperate Asia; southeast of Europe.
Salsify=Tragopogon porrifolium (2)	C. (?)	Southeast of Europe; Algeria.
Scorzonera=Scorzonera hispanica	C.	Southwest of Europe; south of the Caucasus.
Rampion=Campanula rapunculus (2)	C.	Temperate and southern Europe.
Beet=Beta vulg. (2) 4 — Vegetable	B.	Canaries; Mediterranean basin; western temperate Asia.
Beet=Beta vulg. (2) 4 — Root	B.	A result of cultivation.
Garlic=Allium sativum 4	B.	Desert of the Kirghis, in western temperate Asia.

[a] Doctor Bretschneider writes to me from Peking, December 22, 1882, that the species is mentioned in the Ryd, a work of the year 1100 B. C. I do not know if we must suppose the original habitat to be China or western Asia.

Species native to the Old World—Continued.

CULTIVATED FOR THE SUBTERRANEAN PARTS—Continued.

Name and duration.	Date.	Origin.
Onion=Allium cepa (2)	A.	Persia; Afghanistan; Beluchistan; Palestina(?).
Welsh onion=Alliumfi stulosum 4	C.	Siberia (from the land of the Kirghis of Baikal).
Shallot=Allium ascolonicum 4	C.	Modification of A. cepa (?) unknown to wild.
Rocambole=Allium scorodoprassum 4	C.	Temperate Europe.
Chives=Allium schaenoprasum 4	C. (?)	Temperate and northern Europe; Siberia, Khamschatka; North America (Lake Huron).
Taro=Colocasia antiquorum 4	B.	India; Malay Archipelago; Polynesia.
Apé=Alocasia macrorrhiza 4	(?)	Ceylon; Malay Archipelago; Polynesia.
Konjak=Amorphophallus konjak 4	(?)	Japan (?)
Yams=Dioscorea sativa 4	B. (?)	Southern Asia (especially Malabar) (?); Ceylon (?); (Java) (?).
Dioscorea Batatas 4	B. (?)	China (?)
Dioscorea japonica 4	(?)	Japan (?)
Dioscorea alata 4	(?)	East of the Asiatic Archipelago.

CULTIVATED FOR THE STEMS OR LEAVES.

1. VEGETABLES.

Cabbage=Brassica oleracea (1), (2), 5, 7	A.	Europe.
Chinese cabbage=Brassica chinensis (2)	(?)	China (?); Japan (?).
Water cress=Nasturtium officinale 4	(?)	Europe; northern Asia.
Garden cress=Lepidium sativum (1)	B.	Persia (?).
Sea kale=Crambe maritima 4	C.	Western temperate Europe.
Purslane=Portulaca oleracea (1)	A.	From the western Himalayas to southern Russia and Greece.
New Zealand spinach=Tetragonia expansa (1)	C.	New Zealand and New Holland.
Garden celery=Apium graveolens (2)	B.	Temperate and southern Europe; northern Africa; western Asia.
Chervil=Anthriscus cerefolium (1)	C.	Southeast of Russia; western temperate Asia.
Parsley=Petroselium sativum (2)	C.	Southern Europe; Algeria; Lebanon.
Alexanders=Smyrnium olus-atrum (2)	C.	Southern Europe; Algeria; western temperate Asia.
Corn salad=Valerianella olitoria (1)	C.	Sardinia, Sicily.
Cardoon	C.	Southern Europe; northern Africa; Canaries; Madeira.
Artichoke=Cyuara Cardunculus (2) 4 {Cardoon / Artichoke}	C.	Derived from the cardoon.
Lettuce=Latuca scariola (1) (2)	B.	Southern Europe northern Africa; western Asia.
Wild chicory=Cichorium Intybus 4	C.	Europe; northern Africa; western temperate Asia.
Endive=Cichorium Endivia (1)	C.	Mediterranean basin; Caucasus; Turkestan.
Spinach=Spinacia oleracea (1)	C.	Persia (?).
Orach=Atriplex hortensis (1)	C.	Northern Europe and Siberia.
Amaranth=Amarantus gangeticus (1)	(?)	Tropical Africa; India (?).
Sorrel=Rumex acetosa (1) 4	(?)	Europe; northern Asia; mountains of India.
Patience dock=Rumex patientia 4	(?)	Turkey in Europe; Persia.
Asparagus=Asparagus officinalis 4	B.	Europe; western temperate Asia.
Leek=Allium ampeloprasum 4	B.	Mediterranean basin.

2. FODDER.

Lucern=Medicago sativa 4	B.	Western temperate Asia.
Sainfoin=Onobrychis sativa 4	C.	Temperate Europe; south of the Caucasus.
French honeysuckle=Hedysarum coronarium 4	C.	Center and west of the Mediterranean basin.
Purple clover=Trifolium pratense 4	C.	Europe; Algeria; western temperate Asia.
Alsike clover=Trifolium hybridum (1)	C.	Temperate Europe.
Italian clover=Trifolium incarnatum (1)	C.	Southern Europe.
Egyptian clover=Trifolium alexandrinum (1)	C.	Syria; Anatolia.
Ervilla=Ervum Ervilia (1)	B.	Mediterranean basin.
Vetch=Vicia sativa (1)	B.	Europe; Algeria; south of the Caucasns.
Flat-podded pea=Lathyrus Cicera (1)	B.	From Spain and Algeri . to Greece.
Chickling vetch=Lathyrus sativus (1)	B.	South of Caucasus.
Ochrus=Lathyrus ochrus (1)	B.	Italy; Spain.
Fenugreek=Trigonella fœnumgræcum (1)	B.	Northeast of India and western temperate Asia.
Bird's-foot=Ornithopus sativus (1)	B. (?)	Portugal; south of Spain; Algeria.
Nonsuch=Medicago lupulina (1) (2)	C.	Europe; north of Africa (?); temperate Asia.
Corn spurry=Spergula arvensis (1)	B. (?)	Europe.
Guinea grass=Panicum maximum 4	C. (?)	Tropical Africa.

Species native to the Old World—Continued.

CULTIVATED FOR THE STEMS OR LEAVES—Continued.

3. VARIOUS USES.

Name and duration.	Date.	Origin.
Tea=Thea sinensis 6	A.	Assam; China; Manchuria.
Flax anciently cultivated=Linum angustifolium 4 (2) (1).	A.	Mediterranean basin.
Flax now cultivated=Linum usitatissimum (1).	A. (?)	Western Asia (?); derived from the preceding (?).
Jute=Corchorus capsularis (1)	C. (?)	Java; Ceylon.
Jute=Corchorus olitorius (1)	C. (?)	Northwest of India; Ceylon.
Sumach=Rhus coriaria 6	C.	Mediterranean basin; western temperate Asia.
Khat=Celastrus edulis 6	(?)	Abyssinia; Arabia (?).
Indigo=Indigofera tinctoria 6	B.	India (?).
Silver indigo=Indigofera argentea 6	(?)	Abyssinia; Nubia; Kordofan; Sennaar; India (?).
Henna=Lawsonia alba 6	A.	Western tropical Asia; Nubia (?).
Blue gum=Eucalyptus globulus 8	C.	New Holland.
Cinnamon=Cinnamonum zeylanicum 7	C.	Ceylon; India.
China grass=Boehmeria nivea 4, 6	(?)	China; Japan.
Hemp=Cannabis sativa (1)	A.	Dahuria; Siberia.
White mulberry=Morus alba 7	A. (?)	India; Mongolia.
Black mulberry=Morus nigra 7	B. (?)	Armenia; northern Persia.
Sugar cane=Saccharum officinarum 7	B.	Cochin China (?); southwest of China.

CULTIVATED FOR THE FLOWERS OR THEIR ENVELOPES.

Clove=Carophyllus aromaticus 7	(?)	Moluccas.
Hop=Humulus lupulus 4	C.	Europe; western temperate Asia; Siberia.
Carthamine=Carthamus tinctorius (1)	A.	Arabia (?).
Saffron=Crocus sativus 4	A.	Southern Italy; Greece; Asia Minor.

CULTIVATED FOR THE FRUITS.

Shaddock=Citrus decumana 8	B.	Pacific Islands, to the east of Java.
Citron, lemon=Citrus medica 7	B.	India.
Bitter orange=Citrus aurantium bigardia 7	B.	East of India.
Sweet orange=Citrus aurantium sinense 7	C.	China and Cochin China.
Mandarin=Citrus nobilis 7	(?)	Do.
Mangosteen=Garcinia mangostana 7	(?)	Sunda Islands; Malay Peninsula.
Ochro=Hibiscus esculentus (1)	C.	Tropical Africa.
Vine=Vitis vivifera 6	A.	Western temperate Asia; Mediterranean basin.
Common jujube=Zizyphus vulgaris 6	B.	China.
Lotus jujube=Zizyphus lotus 6	(?)	Egypt to Morocco.
Indian jujube=Zizyphus jujuba 6	A. (?)	Burma; India.
Mango=Mangifera indica 6	A. (?)	India.
Tahiti apple=Spondias dulcis 6	(?)	Society, Friendly, and Fiji Isles.
Raspberry=Rubus idæus 6	C.	Temperate Europe and Asia.
Strawberry=Fragaria vesca 6	C.	Temperate Europe and western Asia; east of North America.
Bird cherry=Prunus avium 8	B.	Western temperate Asia; temperate Europe.
Common cherry=Prunus cerasus 7	B.	From the Caspian to western Anatolia.
Plum=Prunus domestica 7	B.	Anatolia; south of the Caucasus; north of Persia.
Plum=Prunus insititia 6	(?)	Southern Europe; Armenia; south of the Caucasus; Talysch.
Apricot=Prunus Armeniaca 7	A.	China.
Almond=Amygdalus communis 7	A.	Mediterranean basin; western temperate Asia.
Peach=Amygdalus persica 7	A.	China.
Common pear=Pyrus communis 8	A.	Temperate Europe and Asia.
Chinese pear=Pyrus sinensis 7	(?)	Mongolia; Manchuria.
Apple=Pyrus malus 7	A.	Europe; Anatolia; south of the Caucasus.
Quince=Cydonia vulgaris 7	A.	North of Persia; south of the Caucasus; Anatolia.
Loquat=Eriobotrya japonica 7	(?)	Japan.
Pomegranate=Punica granatum 8	A.	Persia; Afghanistan; Beluchistan.
Rose apple=Jambosa vulgaris 7	B.	Malay Archipelago; Cochin China; Burma; northeast of India.
Malay apple=Jambosa malaccensis 7	B.	Malay Archipelago; Malacca.
Bottle gourd=Cucurbita lagenaria (1)	C.	India; Moluccas; Abyssinia.
Spanish gourd=C. maxima (1)	C. (?)	Guinea.
Melon=Cucumis melo (1)	C.	India; Beluchistan; Guinea.
Watermelon=Citrullus vulgaris (1)	A.	Tropical Africa.
Cucumber=Cucumis sativus (1)	A.	India.
West Indian gherkin=Cucumis anguria (1)	C. (?)	Tropical Africa. (?)
White gourd-melon=Benincasa hispida (1)	(?)	Japan; Java.
Towel gourd=Luffa cylindrica (1)	C.	India.
Angular luffa=Luffa acutangula (1)	C.	India; Malay Archipelago.

Species native to the Old World—Continued.

CULTIVATED FOR THE FRUITS—Continued.

Name and duration.	Date.	Origin.
Snake gourd=Trichosanthes anguina (1)	C.	India.(?)
Gooseberry=Ribes grossularia 5	C.	Temperate Europe; north of Africa; Caucasus; western Himalayas.
Red currant=Ribis rubrum 5	C.	Northern and temperate Europe; Siberia; Caucasus; Himalayas; northeast of the United States.
Black currant=Ribis nigrum 5	C.	Northern and central Europe; Armenia; Siberia; Manchuria; western Himalayas.
Kaki=Diospyros Kaki 7	(?)	Japan; northern China.
Date plum=Diospyros lotos 7	(?)	China; India; Afghanistan; Persia; Armenia; Anatolia.
Olive=Olea europea 7	A.	Syria; southern Anatolia and neighboring Islands.
Aubergine=Solanum melongena (1)	A.	India.
Fig=Ficus carica 7	A.	Center and south of the Mediterranean basin, from Syria to the Canaries.
Breadfruit=Artocarpus incisa 8	(?)	Sunda Isles.
Jack fruit=Artocarpus integrifolia 8	B.	India.
Date palm=Phoenix dactylifera 8	A.	Western Asia and Africa from the Euphrates to the Canaries.
Banana=Musa sapientum 7	A.	Southern Asia.
Oil palm=Elaeis guincensis 8	(?)	Guinea.

CULTIVATED FOR THE SEEDS.

1. NUTRITIVE.

Litchi=Nephelium Litchi 7	(?)	Southern China; Cochin China.
Longan=Nephelium longana 7	(?)	India; Pegu.
Rambutan=Nephelium lappaceum 7	(?)	Do.
Pistachio=Pistacia vera 6	C.	Syria.
Bean=Fava vulgaris (1)	A.	South of the Caspian (?).
Lentil=Ervum lens (1)	A.	Western temperate Asia; Greece; Italy.
Chick-pea=Cicer arietinum (1)	A.	South of the Caucasus and of the Caspian.
Lupin=Lupinus albus (1)	B.	Sicily; Macedonia; south of the Caucasus.
Egyptian lupin=Lupinus termis (1)	A.	From Corsica to Syria.
Field pea=Pisum arvense (1)	(?)	Italy.
Garden pea=Pisum sativum (1)	B.	From the south of the Caucasus to Persia (?); north India (?).
Soy=Dolichos soja (1) 6	A.	Cochin China; Japan; Java.
Pigeon pea=Cajanus indicus	C.	Equatorial Africa.
Carob=Ceratonia siliqua 8	A. (?)	Southerncoast of Anatolia; Syria; Cyrenaica (?).
Moth=Phaseolus aconitifolius (1)	C.	India.
Three-lobed kidney bean=Phaseolus trilobus 4(1)	B.	India; tropical Africa.
Green gram=Phaseolus mungo 1 (1)	B. (?)	India.
Wall=Phaseolus lablab (1)	C.	Do.
Lubia=Phaseolus lubia (1)	C.	Western Asia (?).
Bambarra ground nut=Voandzeia subterranea (1)	(?)	Intertropical Africa.
Buckwheat=Fagopyrum esculentum (1)	C.	Manchuria; central Siberia.
Tartary buckwheat=Fagopyrum tartaricum (1).	C.	Tartary; Siberia to Dahuria.
Notch-seeded buckwheat=Fagopyrum emarginatum (1).	(?)	Western China; eastern Himalayas.
Kiery=Amarantus frumentaceus (1)	(?)	India.
Chestnut=Castanea vulgaris 4	(?)	From Portugal to the Caspian Sea; eastern Algeria. Varieties: Japan; North America.
Wheat=Triticum vulgare and varieties (?) (1)	A.	Region of the Euphrates.
Spelt=Triticum spelta (1)	A.	Derived from the preceding (?).
One-grained wheat=Triticum monococcum (1)	(?)	Servia; Greece; Anatolia (if the identity with the Triticum boeóticum be admitted).
Two-rowed barley=Hordeum distichon (1)	A.	Western temperate Asia.
Common barley=Hordeum vulgare (1)	(?)	Derived from the preceding (?).
Six-rowed barley=Hordeum hexastichon (1)	A.	Do.
Rye=Secale cereale (1)	B.	Eastern temperate Europe (?).
Common oats=Avena sativa (1)	B.	Do.
Eastern oats=Avena orientalis (1)	C. (?)	Western Asia (?).
Common millet=Panicum miliaceum (1)	A.	Egypt; Arabia.
Italian millet=Panicum italicum (1)	A.	China; Japan; Indian Archipelago (?).
Sorghum=Holcus sorghum (1)	A.	Tropical Africa (?).
Sweet sorghum=Holcus saccharatus (1)	(?)	Do.
Coracan=Eleusine coracana (1)	B.	India.
Rice=Oryza sativa (1)	A.	India; southern China (?).

Species native to the Old World—Continued.

CULTIVATED FOR THE SEEDS—Continued.

2. Various Uses.

Name and duration.	Date.	Origin.
Poppy=Papaver somniferum (1)	B.	Derived from P. setiferum of the Mediterranean basin.
White mustard=Sinapis alba 1	B.	Temperate and southern Europe; north of Africa; western temperate Asia.
Black mustard=Sinapis nigra 1	B.	
Gold of pleasure=Camelina sativa (1)	B. (?)	Temperate Europe; Caucasus; Siberia.
Herbaceous cotton=Gossypium herbaceum 5 (1).	B.	India.
Tree cotton=Gossypium arboreum 6	B. (?)	Upper Egypt.
Arabian coffee=Coffea arabica 7	C.	Tropical Africa; Mozambique; Abyssinia; Guinea.
Liberian coffee=Coffea liberica 8	C.	Guinea; Angola.
Sesame=Sesamum indicum (1)	A.	Sunda Isles.
Nutmeg=Myristica fragrans 7	B.	Moluccas.
Castor-oil plant=Ricinus communis 6	A.	Abyssinia; Sennaar; Kordofan.
Walnut=Juglans regia 8	(?)	Eastern temperate Europe; temperate Asia.
Black pepper=Piper nigrum 6	B.	India.
Long pepper=Piper longum 5	B.	Do.
Medicinal pepper=Piper officinalis 5	B.	Malay Archipelago.
Betel pepper=Piper betle 6	B.	Do.
Areca nut=Areca catechu 7	B.	Do.
Cocoa nut=Cocos nucifera 3	(?)	Malay Archipelago (?); Polynesia (?)

Species of American origin.

CULTIVATED FOR THE UNDERGROUND PARTS.

Arracacha=Arracacha esculenta (1) 4	E.	New Granada (?).
Jerusalem artichoke=Helianthus tuberosus 4	E. (?)	North America (Indiana).
Potato=Solanum tuberosum 4	E.	Chili; Peru (?).
Sweet potato=Convolvulus batatas 4	D.	Tropical America (where?).
Manioc=Manihot utilissima 6	E.	East of tropical Brazil.
Arrowroot=Maranta arundinacea 7	(?)	Tropical (continental?) America.
Maté=Ilex paraguariensis 7	D.	Paraguay and western Brazil.
Coca=Erythroxylon coca 7	D.	East of Peru and Bolivia.
Quinine=Cinchona calisaya 7	F.	Bolivia; southern Peru.
Crown bark=Cinchona officinalis	F.	Ecuador (province of Loxa).
Red cinchona bark=Cinchona succirubra 7	F.	Ecuador (province of Cuenca).
Tobacco={Nicotiana tabacum (1)	D.	Ecuador and neighboring countries.
Tobacco={Nicotiana rustica (1)	E.	Mexico (?); Texas (?); California (?).
American aloe=Agave americana 7	E.	Mexico.

CULTIVATED FOR THE FRUITS.

Sweet sop=Anona squamosa 7	(?)	West India Isles.
Sour sop=Anona muricana	(?)	Do.
Custard apple=Anona reticulata 7	(?)	West India Isles; New Granada.
Chirimoya=Anona cherimolia 7	E.	Ecuador; Peru (?).
Mammee apple=Mammea americana 8	(?)	West India Isles.
Cashew nut=Anacardium occidentale 8	(?)	Tropical America.
Virginian strawberry=Fragaria virginiana 4	F.	Temperate North America.
Chile strawberry=Fragaria chiloensis 4	F.	Chile.
Guava=Psidium guayava 7	E.	Continental Tropical America.
Pumpkin and squash=Cucurbita pepo and Melopepo (1).	E.	Temperate North America.
Prickly pear=Optunia ficus indica 7	E.	Mexico.
Chocho=Sachium edule (1)	E.	Mexico (?); Central America.
Star apple=Chrysophyllum cainito 7	E.	West India Isles; Panama.
Caimito=Lucuma caimito 7	E.	Peru.
Marmalade plum=Lucuma mammosa 7	E.	Valley of the Orinoco.
Sapodilla=Sapota achras 7	E.	Campeachy; Isthmus of Panama; Venezuela.
Persimmon=Diospyros virginiana 7	F.	Eastern States of America.
Annual capsicum=Capsicum annum (1)	E.	Brazil (?).
Shrubby capsicum=Capsicum frutescens 6	E.	From the east of Peru to Bahia.
Tomato=Lycopersicum esculentum (1)	E.	Peru.
Avocado pear=Persea gratissima 8	E.	Mexico.
Papaw=Papaya vulgaris 7	E.	West Indies; Central America.
Pineapple=Ananassa sativa 4	E.	Mexico; Central America; Panama; New Granada; Guiana (?); Bahia (?).

Species of American origin—Continued.

CULTIVATED FOR THE SEEDS.

1. NUTRITIOUS.

Name and duration.	Date.	Origin.
Cacao=Theobroma cacao 7	D.	Amazon and Orinoco valleys; Panama (?); Yucatan (?).
Sugar bean=Phaseolus lunatus 4	E.	Brazil.
Quinoa=Chenopodium quinoa 1	E.	New Granada; Peru (?); Chile (?).
Maize=Zea mays (1)	D.	New Granada (?).

2. VARIOUS USES.

Arnotto=Bixa orellana	D.	Tropical America.
Barbados cotton=Gossypium barbadense 8	(?)	New Granada (?); Mexico (?); West Indies.
Earthnuts=Arachis hypogæa (1)	E.	Brazil.
Madia=Madia sativa (1)	E.	Chile; California.

CRYPTOGRAM CULTIVATED FOR THE WHOLE PLANT.

Mushroom=Agaricus campestris 4	C.	Northern Hemisphere.

Species of unknown or entirely uncertain origin.—Common haricot=Phaseolus vulgaris (1); Musk gourd=Cucurbita moschata (1); Fig-leaved gourd=Cucurbita ficifolia.

GENERAL OBSERVATIONS AND CONCLUSIONS.

REGIONS WHERE CULTIVATED PLANTS ORIGINATED.

In the beginning of the nineteenth century the origin of most of our cultivated species was unknown. Linnæus made no efforts to discover it, and subsequent authors merely copied the vague or erroneous expressions by which he indicated their habitations. Alexander von Humboldt expressed the true state of the science in 1807 when he said: "The origin, the first home of the plants most useful to man, and which have accompanied him from the remotest epochs, is a secret as impenetrable as the dwelling of all our domestic animals. * * * We do not know what region produced spontaneously wheat, barley, oats, and rye. The plants which constitute the natural riches of all the inhabitants of the Tropics, the banana, the papaw, the manioc, and maize, have never been found in a wild state. The potato presents the same phenomenon." [a]

At the present day, if a few cultivated species have not yet been seen in a wild state, this is not the case with the immense majority. We know at least, most frequently, from what country they first came. This was already the result of my work of 1855, with modern and more extensive research has confirmed in almost all points. This research has been applied to 247 species,[b] cultivated on a large scale by agriculturists or in kitchen gardens and orchards. I might have added a few rarely cultivated or but little known, or of which the cultivation has been abandoned, but the statistical results would be essentially the same.

Out of the 247 species which I have studied, the Old World has furnished 199, America 45, and 3 are still uncertain.

[a] Essai sur la Geographie des plantes, p. 28.
[b] Counting two or three forms which are perhaps rather very distinct races.

No species was common to the tropical and austral regions of the two hemispheres before cultivation. *Allium schoenoprasum*, the hop (*Humulus lupulus*), the strawberry (*Fragaria vesca*), the currant (*Ribis rubrum*), the chestnut (*Castanea vulgaris*), and the mushroom (*Agaricus campestris*) were common to the northern regions of the Old and New Worlds. I have reckoned them among the species of the Old World, since their principal habitation is there and there they were first cultivated.

A great number of species originated at once in Europe and western Asia, in Europe and Siberia, in the Mediterranean basin and western Asia, in India and the Asiatic Archipelago, in the West Indies and Mexico, in these two regions and Colombia, in Peru and Brazil, or in Peru and Colombia, etc., etc. They may be counted in the table. This is a proof of the impossibility of subdividing the continents and of classing the islands in well-defined natural regions. Whatever be the method of division, there will always be species common to two, three, four, or more regions, and others confined to a small portion of a single country. The same facts may be observed in the case of uncultivated species.

A noteworthy fact is the absence in some countries of indigenous cultivated plants. For instance, we have none from the Arctic or Antarctic regions, where, it is true, the floras consist of but few species. The United States, in spite of their vast territory, which will soon support hundreds of millions of inhabitants, only yield, as nutritious plants worth cultivating, the Jerusalem artichoke and the gourds. *Zizana æquatica*, which the natives gathered wild, is a grass too inferior to our cereals and to rice to make it worth the trouble of planting it. They had a few bulbs and edible berries, but they have not tried to cultivate them, having early received the maize, which was worth far more.

Patagonia and the Cape have not furnished a single species. Australia and New Zealand have furnished one tree, *Eucalyptus globulus*, and a vegetable, not very nutritious, the *Tetragonia*. Their floras were entirely wanting in graminæ similar to the cereals, in leguminous plants with edible seeds, in Cruciferæ with fleshy roots.[a] In the moist tropical region of Australia, rice and *Alocasia macrorrhiza* have been found wild, or perhaps naturalized, but the greater part of the country suffers too much from drought to allow these species to become widely diffused.

In general, the austral regions had very few annuals, and among their restricted number none offered evident advantages. Now annual species are the easiest to cultivate. They have played a great part in the ancient agriculture of other countries.

In short, the original distribution of cultivated species was very unequal. It had no proportion with the needs of man or the extent of territory.

NUMBER AND NATURE OF CULTIVATED SPECIES AT DIFFERENT EPOCHS.

The species marked A in the table on pages 437–446 must be regarded as of very ancient cultivation. They are 44 in number. Some

[a] See the list of the useful plants of Australia by Sir J. Hooker, Flora Tasmania, p. cx.; and Bentham, Flora Australiensis, vii, p. 156.

of the species marked B are probably as ancient, though it is impossible to prove it. The five American species marked D are especially plants provided with roots, seeds, and fruits proper for the food of man. Afterwards come a few species having fruits agreeable to the taste, or textile, tinctorial, oil-producing plants, or yielding drinks by infusion or fermentation. There are among these only two green vegetables and no fodder. The orders which predominate are the Cruciferæ, Leguminosæ, and Graminaceæ.

The number of annuals is twenty-two out of the forty-four, or 50 per cent. Out of five American species marked D, two are annuals. In the category A there are two biennials, and D has none. Among all the Phanerogams the annuals are not more than 50 per cent, and the biennials 1 or at most 2 per cent. It is clear that at the beginning of civilization plants which yield an immediate return are most prized. They offer, moreover, this advantage, that their cultivation is easily diffused or increased, either because of the abundance of seed or the same species may be grown in summer in the North, and in winter or all the year round in the Tropics.

Herbaceous perennial plants are rare in categories A and D. They are only from 2 to 4 per cent, unless we include *Brassica oleracea* and the variety of flax which is usually perennial (*L. angustifolium*), cultivated by the Swiss lake dwellers. In nature, herbaceous perennials constitute about 40 per cent of the Phanerogams.[a]

A and D include twenty ligneous species out of forty-nine, that is about 41 per cent. They are in the proportion of 43 per cent of the Phanerogams.

Thus the earliest husbandmen employed chiefly annuals or biennials, rather fewer woody species, and far fewer herbaceous perennials. These differences are due to the relative facility of cultivation and the proportion of the evidently useful species in each division.

The species of the Old World marked B have been in cultivation for more than two thousand years, but perhaps some of them belong to category A. The American species marked E were cultivated before the discoveries of Columbus, perhaps for more than two thousand years. Many other species marked "(?)" in the table date probably from an ancient epoch, but as they chiefly exist in countries without a literature and without archæological records, we do not know their history. It is useless to insist upon such doubtful categories; on the other hand, the plants which we know to have been first cultivated in the Old World less than two thousand years ago, and in America since its discovery, may be compared with plants of ancient cultivation.

These species of modern cultivation number 61 in the Old World, marked C, and 6 in America, marked F; 67 in all.

Classed according to their duration, they number 37 per cent annuals, 7 to 8 per cent biennials, 33 per cent herbaceous perennials, and 22 to 23 per cent woody species.

The proportion of annuals or biennials is also here larger than in the whole number of plants, but it is not so large as among species of very ancient cultivation. The proportions of perennials and woody

[a] The proportions which I give for the Phanerogams collectively are based upon an approximative calculation made with the aid of the first 200 pages of Steudel's Nomenclator. They are justified by the comparison with several floras.

species are less than in the whole vegetable kingdom, but they are higher than among the species A of very ancient cultivation.

The plants cultivated for less than two thousand years are chiefly artificial fodders, which the ancients scarcely knew; then bulbs, vegetables, medicinal plants (Cinchonas), plants with edible fruits, or nutritious seeds (buckwheats), or aromatic seeds (coffee).

Men have not discovered and cultivated within the last two thousand years a single species which can rival maize, rice, the sweet potato, the potato, the breadfruit, the date cereals, millets, sorghums, the banana, and soy. These date from three, four, or five thousand years, perhaps even in some cases six thousand years. The species first cultivated during the Græco-Roman civilization and later nearly all answer to more varied or more refined needs. A great dispersion of the ancient species from one country to another took place, and at the same time a selection of the best varieties developed in each species. The introductions within the last two thousand years took place in a very irregular and intermittent manner. I can not quote a single species cultivated for the first time after that date by the Chinese, the great cultivators of ancient times. The peoples of southern and western Asia innovated in a certain degree by cultivating the buckwheats, several cucurbitaceæ, a few alliums, etc. In Europe the Romans and several peoples in the Middle Ages introduced the cultivation of a few vegetables and fruits and that of several fodders. In Africa a few species were then first cultivated separately. After the voyages of Vasco di Gama and of Columbus a rapid diffusion took place of the species already cultivated in either hemisphere. These transports continued during three centuries without any introduction of new species into cultivation. In the two or three hundred years which preceded the discovery of America and the two hundred which followed, the number of cultivated species remained almost stationary. The American strawberries, *Diospyros virginiana*, sea kale, and *Tetragonia expansa*, introduced in the eighteenth century, have but little importance. We must come to the middle of the present century to find new cultures of any value from the utilitarian point of view, such as *Eucalyptus globulus* of Australia and the *Cinchonas* of South America.

The mode of introduction of the latter species shows the great change which has taken place in the means of transport. Previously the cultivation of a plant began in the country where it existed, whereas the Australian *Eucalyptus* was first planted and grown in Algeria, and the *Cinchonas* of America in the south of Asia. Up to our own day botanical or private gardens had only diffused species already cultivated somewhere; now they introduce absolutely new cultures. The royal garden at Kew is distinguished in this respect, and other botanical gardens and acclimatization societies in England and elsewhere are making similar attempts. It is probable that tropical countries will greatly benefit by this in the course of a century. Others will also find their advantage from the growing facility in the transport of commodities.

When a species has been once cultivated it is rarely, perhaps never, completely abandoned. It continues to be here and there cultivated in backward countries or those whose climate is especially favorable. I have passed over some of these species which are nearly abandoned, such as dyer's woad (*Isatis tinctoria*), mallow (*Malva sylvestris*), a vegetable used by the Romans, and certain medicinal plants formerly much used, such as fennel, cummin, etc.; but it is certain that they are still grown in some places.

The competition of species causes the cultivation of some to diminish, of others to increase; besides, vegetable dyes and medicinal plants are rivaled by the discoveries of chemists. Woad, madder, indigo, mint, and several simples must give way before the invasion of chemical products. It is possible that men may succeed in making oil, sugar, and flour, as honey, butter, and jellies are already made, without employing organic substances. Nothing, for instance, would more completely change agricultural conditions than the manufacture of flour from its own inorganic elements. In the actual state of science there are still products which will be more and more required of the vegetable kingdom; these are textile substances, tan, india rubber, gutta-percha, and certain spices. As the forests where these are found are gradually destroyed, and these substances are at the same time more in demand, there will be the greater inducement to cultivate certain species.

These usually belong to tropical countries. It is in these regions also, particularly in South America, that fruit trees will be more cultivated—those of the order Anonaceæ, for instance, of which the natives and botanists already recognize the value. Probably the number of plants suitable for fodder and of forest trees which can live in hot, dry countries will be increased. The additions will not be numerous in temperate climates, nor especially in cold regions.

From these data and reflections it is probable that at the end of the nineteenth century men will cultivate on a large scale and for use about 300 species. This is a small proportion of the 120,000 or 140,000 in the vegetable kingdom; but in the animal world the proportion of creatures subject to the will of man is far smaller. There are not perhaps more than 200 species of domestic animals—that is, reared for our use—and the animal kingdom reckons millions of species. In the great class of molluscs the oyster alone is cultivated, and in that of the Articulata, which counts ten times more species than the vegetable kingdom, we can only name the bee and two or three silk-producing insects. Doubtless the number of species of animals and vegetables which may be reared or cultivated for pleasure or curiosity is very large—witness menageries and zoological and botanical gardens—but I am only speaking here of useful plants and animals in general and customary employment.

CULTIVATED PLANTS KNOWN OR NOT KNOWN IN A WILD STATE.

Science has succeeded in discovering the geographical origin of nearly all cultivated species; but there is less progress in the knowledge of species in a natural state—that is, wild, far from cultivation and dwellings. There are species which have not been discovered in this condition and others whose specific identity and truly wild condition are doubtful.

In the following enumeration I have classed the species according to the degree of certainty as to the wild character, and the nature of the doubts where such exist.[a]

[a] The species in italics are of very ancient cultivation (A or D); those marked with an asterisk have been less than two thousand years in cultivation (C or F).

1. Spontaneous species—that is, wild—seen by several botanists far from dwellings and cultivation, with every appearance of indigenous plants, and under a form identical with one of the cultivated varieties. These are the species which are not enumerated below; they are 169 in number.

Among these 169 species 31 belong to the categories A and D, of very ancient cultivation, 56 have been in cultivation less than two thousand years, C, and the others are of modern or unknown date.

2. Seen and gathered in the same conditions, but by a single botanist in a single locality. Three species: Cucurbita maxima, *Faba vulgaris*, *Nicotiana Tabacum.*

3. Seen and mentioned but not gathered in the same conditions by one or two authors and botanists, more or less ancient, who may have been mistaken. Two species: *Carthamus tinctorius*, *Triticum vulgare.*

4. Gathered wild by botanists in several localities under a form slightly different to those which are cultivated, but which most authors have no hesitation in classing with the species. Four species: *Olea europæa*, *Oryza sativa*, Solanum tuberosum, *Vitis virifera.*

5. Wild, gathered by botanists in several localities under forms considered by some botanists as constituting different species, while others treat them as varieties. Fifteen species: Allium ampeloprasum porrum, Cichorium Endivia, var. *Crocus sativus*, var., *Cucumis melo, Cucurbita Pepo, Helianthus tuberosus, Latuca scariola sativa, *Linum usitatissimum annuum*, Lycopersicum esculentium, Papaver somniferum, Pyrus nivalis var., *Ribis grossularia, Solanum Melongena, Spinacia oleracea var., Triticum monococcum.

6. Subspontaneous—that is, half-wild—similar to one or other of the cultivated forms, but possibly plants escaped from cultivation, judging from the locality. Twenty-four species: Agava americana, Amarantus gangeticus, *Amygdalus persica*, Areca catechu, *Avena orientalis, Avena sativa, Cajanus indicus, *Cicer arietinum*, Citrus decumana, Cucurbita mischota, Dioscorea japonica, Ervum Ervilia, *Ervum lens*, Fagopyrum emarginatum, Gossypium barbadense, Holcus saccharatus, *Holcus sorghum*, Indigofera tinctoria, Lepidum sativum, Maranta arundinacea, Nicotiana rustica, *Panicum miliaceum*, Raphanus sativus, Spergula arvensis.

7. Subspontaneous like the preceding, but different enough from cultivated varieties to lead the majority of authors to regard them as distinct species. Three species: *Allium ascalonicum (variety of *A. cepa ?*), Allium scorodoprasum (variety of A. sativum ?), Secale cereale (variety of one of the perennial species of Secale ?).

8. Not discovered in a wild state, nor even half-wild, derived perhaps from cultivated species at the beginning of agriculture, but too different not to be commonly regarded as distinct species. Three species: *Hordeum hexastichon* (derived from *H. distichon?*), *Hordeum vulgare* (derived from *H. distichon?*), *Triticum spelta* (derived from *T. vulgare?*).

9. Not discovered in a wild state, nor even half-wild, but originating in countries which are not completely explored, and belonging perhaps to little known wild species of these countries. Six species: Arachis hypogea, Carophyllus aromaticus, *Convolvulus batatas*, Dolichos lubia, Manihot utilissima, *Phaseolus vulgaris.*

10. Not found in a wild state, nor even half-wild, but originating in countries which are not sufficiently explored, or in similar countries, which can not be defined, more different than the latter from known wild species. Eighteen species: Amorphophallus konjak, Arracacha esculenta, Brassica chinensis, Capsicum annuum, Chenopodium quinoa,[a] Citrus nobilis, Cucurbita ficifolia. Dioscorea alata, Dioscorea Batatas, Dioscorea sativa, Eleusine coracana, Lucuma mammosa, Nephelium Litchi, Pisum sativum, Saccharum officinarum, Sechium edule, Triconsanthes anguina, *Zea mays*.

Total, 247 species.

These figures show that there are 193 species known to be wild, 27 doubtful, as half-wild, and 27 not found wild.

I believe that these last will be found some time or other, if not under one of the cultivated forms, at least in an allied form called species or variety, according to the author. To attain this result, tropical countries will have to be more thoroughly explored, collectors must be more attentive to localities, and more floras must be published of countries now little known, and good monographs of certain genera based upon the characters which vary least in cultivation.

A few species, having their origin in countries fairly well explored, and which it is impossible to confound with others, because each is unique in its genus, have not been found wild, or only once, which leads us to suppose that they are extinct in nature or rapidly becoming so. I allude to maize and the bean. (See pp. 316 and 387.) I mention also, in Article IV, other plants which appear to be becoming extinct in the last few thousand years. These last belong to genera which contain many species, which renders the hypothesis less probable;[b] but on the other hand, they are rarely seen at a distance from cultivated ground, and they hardly ever become naturalized, that is, wild, which shows a certain feebleness or a tendency to become the prey of animals and parasites.

The 67 species cultivated for less than two thousand years (C, F) are all found wild, except the species marked with an asterisk, which have not been found or which are subject to doubts. This is a proportion of 83 per cent.

What is more remarkable is that the great majority of species cultivated for more than four thousand years (A), or in America for three thousand or four thousand years (D), still exist wild in a form identical with some one of the cultivated varieties. Their number is 31 out of 49, or 63 per cent. In categories 9 and 10 there are only 2 of these species of very ancient cultivation, or 4 per cent, and these are 2 species which probably exist no longer as wild plants.

I believe, a priori, that a great number of the species cultivated for more than four thousand years would have altered from their original condition to such a degree that they could no longer be recognized among wild plants. It appears, on the contrary, that the forms anterior to cultivation have commonly remained side by side with those which cultivators employed and propagated from century to century. This may be explained in two ways: (1) The period of

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[a] Since this list was printed I have been informed that the quinoa is wild in Chili. Some of the figures need modification in consequence of this error.

[b] For reasons which I can not here express, monotypical genera are for the most part in process of extinction.

four thousand years is short compared to the duration of most of the specific forms in phanerogamous plants. (2) The cultivated species receive, outside of cultivated ground, continual reenforcements from the seeds which man, birds, and different natural agents disperse and transport in a thousand ways. Naturalization produced in this manner often confounds the wild plants with the cultivated ones, and the more easily that they fertilize each other since they belong to the same species. This fact is clearly demonstrated in the case of a plant of the Old World cultivated in America, in gardens, and which later becomes naturalized on a large scale in the open country or the woods, like the cardoon at Buenos Aires, and the oranges in several American countries. Cultivation widens areas, and supplements the deficits which the natural reproduction of the species may present. There are, however, a few exceptions, which are worth mentioning in a separate article.

CULTIVATED PLANTS WHICH ARE EXTINCT OR BECOMING EXTINCT IN A WILD STATE.

These species to which I allude present three remarkable characters:

1. They have not been found wild, or only once or twice, and often doubtfully, although the regions whence they come have been visited by several botanists.
2. They have not the faculty of sowing themselves, and propagating indefinitely outside cultivated ground; in other terms, in such cases they do not pass out of the condition of adventitious plants.
3. It can not be supposed that they are derived within historic times from certain allied species.

These three characters are found united in the following species: Bean (*Faba vulgaris*), chick-pea (*Cicer arietinum*), ervilla (*Ervum ervilia*), lentil (*Ervum lens*), tobacco (*Nicotiana tabacum*), wheat (*Triticum vulgare*), *maize* (*Zea mays*). The sweet potato (*Convolvulus batatas*) should be added if the kindred species were better known to be distinct, and the carthamine (*Carthamus tinctorius*) if the interior of Arabia had been explored and we had not found a mention of the plant in an Arabian author.

All these species, and probably others of little-known countries or genera, appear to be extinct or on their way to become so. Supposing they ceased to be cultivated, they would disappear, whereas the majority of cultivated plants have become somewhere naturalized and would persist in a wild state.

The seven species mentioned just now, excepting tobacco, have seeds full of fecula, which are the food of birds, rodents, and different insects, and have not the power of passing entire through their alimentary canal. This is probably the sole or principal cause of their inferiority in the struggle for existence.

Thus my researches into cultivated plants show that certain species are extinct or becoming extinct since the historical epoch, and that not in small islands but on vast continents without any great modifications of climate. This is an important result for the history of all organic beings in all epochs.

CONCLUDING REMARKS.

1. Cultivated plants do not belong to any particular category, for they belong to 51 different families. They are, however, all phanerogamous except the mushroom (*Agaricus campestris*).

2. The characters which have most varied in cultivation are, beginning with the most variable: (*a*) The size, form, and color of the fleshy parts, whatever organ they belong to (root, bulb, tubercle, fruit, or seed) and the abundance of fecula, sugar, and other substances which are contained in these parts; (*b*) the number of seeds, which is often in inverse ratio to the development of the fleshy parts of the plant; (*c*) the form, size, or pubescence of the floral organs which persist around the fruits or seeds; (*d*) the rapidity of the phenomena of vegetation, whence often results the quality of ligneous of herbaceous plants, and of perennial, biennial, or annual.

The stems, leaves, and flowers vary little in plants cultivated for those organs. The last formations of each yearly or biennial growth vary most; in other terms, the results of vegetation vary more than the organs which cause vegetation.

3. I have not observed the slightest indication of an adaptation to cold. When the cultivation of a species advances toward the north (maize, flax, tobacco, etc.) it is explained by the production of early varieties, which can ripen before the cold season, or by the custom of cultivating in the north in summer the species which in the south are sown in winter. The study of the northern limits of wild species had formerly led me to the same conclusion, for they have not changed within historic times, although the seeds are carried frequently and continually to the north of each limit. Periods of more than four or five thousand years or changements of form and duration are needed apparently to produce a modification in a plant which will allow it to support a greater degree of cold.

4. The classification of varieties made by agriculturists and gardeners is generally based on those characters which vary most (form, size, colors, taste of the fleshy parts, beard in the ears of corn, etc.). Botanists are mistaken when they follow this example; they should consult those more fixed characters of the organs for the sake of which the species are not cultivated.

5. A noncultivated species being a group of more or less similar forms, among which subordinate groups may often be distinguished (races, varieties, subvarieties), it may have happened that two or more of these slightly differing forms may have been introduced into cultivation. This must have been the case especially when the habitation of a species is extensive, and yet more when it is disjunctive. The first case is probably that of the cabbage (*Brassica*), of flax, bird cherry (*Prunus avium*), the common pear, etc. The second is probably that of the gourd, the melon, and trefoil haricot, which existed previous to cultivation both in India and Africa.

6. No distinctive character is known between a naturalized plant which arose several generations back from a cultivated plant and a wild plant sprung from plants which have always been wild. In any case, in the transition from cultivated plant to wild plant the particular features which are propagated by grafting are not preserved by seedlings. For instance, the olive tree which has become wild is the *oleaster*, the pear bears smaller fruits, the Spanish chestnut yields a

common fruit. For the rest, the forms naturalized from cultivated species have not yet been sufficiently observed from generation to generation. M. Sagot has done this for the vine. It would be interesting to compare in the same manner with their cultivated forms Citrus, Persica, and the cardoon, naturalized in America, far from their original home, as also the Agave and the prickly pear, wild in America, with their naturalized varieties in the Old World. We should know exactly what persists after a temporary state of cultivation.

7. A species may have had, previous to cultivation, a restricted habitation, and subsequently occupy an immense area as a cultivated and sometimes a naturalized plant.

8. In the history of cultivated plants I have noticed no trace of communication between the peoples of the Old and New worlds before the discovery of America by Columbus. The Scandinavians, who had pushed their excursions as far as the north of the United States, and the Basques of the Middle Ages, who followed whales perhaps as far as America, do not seem to have transported a single cultivated species. Neither has the Gulf Stream produced any effect. Between America and Asia two transports of useful plants perhaps took place, the one by man (the Batata, or sweet potato), the other by the agency of man or of the sea (the cocoanut palm).

THE PRINCIPAL DROUGHTS IN THE PERIOD FROM 1870 TO 1906 AND THEIR INFLUENCE ON THE CORN CROP.

By A. F. WOODS,
Assisted by E. H. BRADLEY,
Bureau of Plant Industry, U. S. Department of Agriculture.

Prof. A. J. Henry, in the Yearbook of the Department of Agriculture for 1907, stated:

The years of minimum rainfall or drought from 1871 to 1896 fall in groups separated by irregular intervals. The first group centers about 1871; the second, 1881; the third, 1887; and the last, 1894–95. The drought of 1887 was severe in some months, but not consistently so throughout the entire season. The droughts of 1881 and 1894 were widespread and severe. The former was confined principally to States east of the Alleghenies, while the latter was felt from Nebraska eastward to Massachusetts and southward to Alabama.

Prior to 1870 the few records available indicate a severe drought in 1860 in Kansas and western Missouri, more severe than has since been experienced. Widespread drought in the central valleys and Lake region also occurred in 1863. The periods of extensive drought in chronological order are, therefore, 1860, 1863, 1870–71, 1881, 1887, and 1894–95.[a]

There have been, of course, several local droughts in various portions of the United States during the intervening years, as there must always be in a territory of such vast extent.

The smallest amount (of rainfall) that may be expected in the great corn and wheat regions of the central valleys does not vary greatly from 9 to 10 inches (from April 1 to September 30). In the South Atlantic and Gulf States the fall in the year of least rain ranges from a maximum of 20 inches in central and northern Florida to less than 15 inches in the Mississippi Valley and a considerable fringe of country to the westward. The amount of rain that falls in the year of severe drought in the greater part of the Southeastern States is sufficient for the growth and maturity of staple crops if properly distributed. Success in agricultural pursuits, so far as conditioned upon the rainfall, should therefore be more easily achieved in the Southeastern States than elsewhere, particularly in regions of precarious rainfall.[b]

In Bulletin Q of the Weather Bureau, Climatology of the United States, by Henry, published in 1906, attention is called especially to the severe droughts of 1870, 1874, 1881, 1886, 1887, 1893, 1894, and 1895. The following pages contain extracts from Bulletin Q and data obtained from articles on weather and crop conditions, published annually in the Yearbooks of the Department of Agriculture.

DROUGHT OF 1870.

Local in character; southern Ohio, Wisconsin, and Missouri.

In southern Ohio the rainfall from August 1 to September 30 was about $1\frac{1}{4}$ inches.

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[a] In addition to the drought years mentioned above, a severe drought occurred in 1901, which cut the corn crop very short. This drought prevailed from June 24 to July 29—thirty-six days—over the States of the central valleys and middle Rocky Mountain region, and also in lesser degree in the Lake region, the Ohio Valley, and Tennessee. A very serious drought also prevailed during 1890 over the greater portion of the corn belt.

[b] A. J. Henry, Rainfall of the Crop Season, Yearbook, U. S. Dept. Agr., 1897.

At Milwaukee the precipitation for April was ½ inch; May, $\frac{6}{10}$ inch; June, 2½ inches.

Dry weather also prevailed in Missouri.

The drought apparently had no effect on corn; in fact, the average crops were greater for 1870 than for preceding year, being 6 bushels above the average for forty years in Ohio, 7 above Wisconsin, but 3 below the average in Missouri.

DROUGHT OF 1874.

A severe drought prevailed in Kansas, Nebraska, Iowa, Missouri, Illinois, and Indiana, and in less marked degree in the middle and lower Mississippi valleys.

Eastern Kansas was affected the worst, where for a period of eighty days slightly over 2 inches of rain fell. At Leavenworth, Kans., from June 15 to July 8—twenty-four days—practically no rain fell.

Average yield of corn in bushels per acre.

State.	1873.	1874.	1875.	Normal.
Indiana	25.6	27.0	34.0	31.4
Illinois	21.0	18.0	34.3	30.3
Iowa	29.0	29.2	35.0	32.4
Missouri	23.5	16.0	36.6	28.5
Nebraska	35.0	10.0	40.0	30.4
Kansas	39.1	10.5	40.0	27.2
Kentucky	29.5	25.0	33.3	26.4
Tennessee	22.5	16.8	26.5	22.1
Mississippi	15.5	13.8	18.0	15.0
Louisiana	16.5	15.5	15.5	16.8
Arkansas	23.5	12.6	30.0	21.0

NOTE.—This drought prevailed in 11 States, 8 of which showed reduced production of corn as compared with the previous year (1873), and all showed lower yields than those of the following year (1875). The yields in all these States were also below the normal for the forty years, being 4 below in Indiana, 12 below in Illinois, 3 in Iowa, 14 in Missouri, 20 in Nebraska, 17 in Kansas, 1½ in Kentucky, 5 in Tennessee, 1 in Mississippi, 1 in Louisiana, and 8 in Arkansas.

DROUGHT OF 1876.

A severe drought occurred this year in New England, the Middle Atlantic States, the Ohio Valley, and lower Lake region; it also prevailed quite generally south of the Ohio River and east of the Mississippi. No figures as to precipitation are available.

Only in the following States of the affected region, however, did the corn yield fall below the normal for the forty-year period, 1867–1906:

Average yield of corn in bushels per acre.

State.	1875.	1876.	1877.	Normal.
Maine	30.5	31.0	36.0	33.2
New York	34.0	30.0	32.0	31.0
South Carolina	10.2	8.2	9.0	9.7
Indiana	34.0	30.0	30.0	31.4
Illinois	34.3	25.0	29.0	30.3

DROUGHT OF 1881.

This was a year of serious drought, which affected practically the entire country east of the Mississippi River and lasted from July to September.

The precipitation at Indianapolis from June 22 to August 30 (seventy days) was 1½ inches; at Indianapolis, May 15 to June 4 (twenty-one days), less than ½ inch; at Pittsburg, Pa., from May 7 to May 29 (twenty-three days), $\frac{6}{10}$ inch; June 18 to July 15 (twenty-eight days), 1 inch; August 1 to September 25 (fifty-six days), 1¼ inches.

Average yield of corn in bushels per acre.

State.	1880.	1881.	1882.	Normal.
Maine	35.4	35.4	29.2	33.2
New Hampshire	38.0	34.2	23.4	35.0
Vermont	32.0	35.7	33.9	35.0
Massachusetts	33.5	25.1	21.7	34.8
Rhode Island	30.0	27.0	23.0	30.4
Connecticut	29.0	25.5	20.1	32.5
New York	34.8	26.4	27.5	31.0
New Jersey	41.0	23.2	28.9	34.2
Pennsylvania	40.6	25.2	31.3	33.3
Delaware	32.0	14.4	18.9	32.8
Maryland	32.0	24.2	25.9	26.7
Virginia	25.0	15.0	19.1	19.2
West Virginia	30.0	22.7	25.4	25.9
North Carolina	16.4	11.7	14.0	13.5
South Carolina	9.3	6.7	12.0	9.7
Georgia	9.2	8.3	13.3	11.0
Florida	9.4	8.8	9.5	9.9
Ohio	37.5	25.4	31.3	33.0
Indiana	29.0	21.8	31.3	31.4
Illinois	27.2	19.4	23.0	30.3
Michigan	40.7	28.0	30.7	30.8
Wisconsin	33.0	27.6	28.8	31.2
Kentucky	29.1	17.0	24.3	26.7
Tennessee	22.4	12.4	24.1	22.1
Alabama	12.4	9.9	13.9	13.1
Mississippi	14.6	11.0	16.8	15.0
Louisiana	19.0	13.0	18.5	16.8
Texas	25.0	11.9	19.3	20.0
Arkansas	25.0	14.8	21.6	21.0
Iowa	38.0	25.8	25.9	32.4
Missouri	28.4	16.5	29.5	28.5
Nebraska	31.0	27.4	34.9	30.4
Kansas	29.3	18.2	33.7	27.2

In every State east of the Mississippi River, with the exception of Maine, New Hampshire, and Vermont, the yield was lower than for the preceding year, 1880, and in nearly every case lower also than for the yields for the following year, 1882. This was true also of the yield as compared with the average for the forty-year period.

The production of corn in California, Oregon, and Nevada was also below the forty-year average for this year. For the whole country the average yield was 18.6 bushels, as compared with 25.5 bushels for the forty years—the lowest annual average for the forty-year period, with the exception of the year 1901.

DROUGHTS OF 1886 AND 1887.

1886.—Severe drought in Kansas, Nebraska, the Dakotas, Iowa, Minnesota, and western Wisconsin.

1887.—This year was also characterized by a severe and prolonged drought over the Ohio Valley, Michigan, Indiana, Illinois, Missouri, Iowa, Nebraska, Kansas, Minnesota, Louisiana, Mississippi, Alabama, and portions of the Middle Atlantic States.

At Iowa City, Iowa, from May 13 to the end of July, 1886, a period of 83 days, 0.95 inch of rain fell, being scarcely 1 per cent of the normal.

"The drought of 1887 was severe in some months, but not consistently so throughout the entire season." (A. J. Henry, in Yearbook, 1897.)

Average yield of corn in bushels per acre.

State.	1885.	1886.	1887.	1888	Normal.
New York [a]	30.7	31.3	33.0	32.4	31.0
New Jersey [a]	32.0	27.2	30.0	32.4	34.2
Pennsylvania [a]	32.5	28.2	32.2	32.5	33.3
Delaware [a]	19.3	16.6	20.0	17.4	22.8
Maryland [a]	22.0	20.9	27.0	23.7	26.7
Virginia [a]	14.9	15.5	17.5	16.3	19.2
West Virginia [a]	23.8	22.8	19.0	23.8	25.9
Ohio [a]	37.1	32.2	26.3	32.5	33.0
Indiana [a]	35.5	31.9	20.0	34.8	31.4
Illinois [a]	31.4	34.5	19.2	35.7	30.3
Michigan [a]	32.7	29.1	22.5	30.0	30.8
Wisconsin [b]	30.1	25.7	25.3	30.6	31.2
Minnesota [a b]	28.4	29.8	29.8	29.3	30.0
Iowa [a b]	32.1	25.1	25.5	35.8	32.4
Missouri [a]	31.3	22.2	22.0	31.0	28.5
Dakota [b]	28.9	23.9	33.0	25.5	23.2
Nebraska [a b]	36.7	27.4	24.1	35.2	30.4
Kansas [a b]	32.4	21.8	14.6	26.7	27.2
Kentucky [a]	25.5	25.2	18.3	25.8	26.4
Tennessee [a]	21.2	20.7	21.5	20.8	22.1
Alabama [a]	13.4	12.1	13.6	12.7	13.1
Mississippi [a]	13.4	13.1	17.3	14.7	15.0
Louisiana [a]	16.8	15.6	18.0	14.8	16.8

[a] 1887. [b] 1886.

The area of the drought of 1886 probably also extended over the eastern part of the country, although data are lacking on this point. An examination of the foregoing figures, however, shows marked reductions in yield for this year in New Jersey, Pennsylvania, Delaware, Maryland, and Virginia, doubtless due to drought.

The drought of 1887 appears, from a study of the figures, to have been particularly severe in the Ohio Valley and Lake region, and in the central Mississippi and Missouri valleys, where reductions in yield from the normal of from 6 to 13 bushels per acre were noted.

DROUGHT OF 1890.

Beginning with July, a drought of considerable proportions began over the greater part of the States embraced within the corn belt, the amount of precipitation for the month ranging, at many points, from 50 to less than 25 per cent of the average fall. Reports from numerous correspondents over the above-mentioned section indicate that corn was suffering seriously from the prevailing dry weather. The deficiency in rainfall continued during August and into September over a large portion of the more northern and western States of the corn belt.

Average yield of corn in bushels per acre.

State.	1889.	1890.	1891.	Normal.
New York	29.3	26.6	31.8	31.0
New Jersey	30.2	31.3	34.2	34.2
Pennsylvania	29.8	27.5	33.3	33.3
Delaware	17.5	18.5	22.0	22.8
Maryland	20.6	22.5	25.5	26.7
Virginia	15.9	17.5	19.7	19.2
West Virginia	22.4	20.0	27.3	25.9
Ohio	29.6	23.5	32.0	33.0
Indiana	29.0	24.7	33.3	31.4
Illinois	32.3	26.2	33.5	30.3
Michigan	23.5	26.7	29.5	30.8
Iowa	39.5	26.0	36.7	32.4
Missouri	32.2	25.8	29.9	28.5
Nebraska	36.5	18.0	35.2	30.4
Kansas	35.3	15.6	26.7	27.2
Kentucky	26.5	22.6	30.0	26.4
Tennessee	22.0	18.8	22.7	22.1
Alabama	13.5	10.2	12.7	13.1
Mississippi	14.8	12.5	15.2	15.0
Louisiana	17.5	16.0	17.3	16.8
Texas	18.3	15.5	19.5	20.0
Arkansas	20.0	16.7	21.2	21.0
The Dakotas	18.0	13.6	....	23.2
Colorado	25.4	18.2	21.5	22.0

While the above figures call attention to the principal States affected by the drought of 1890, with the exception of most of the New England States and South Carolina, every State in the Union showed reduced yields of corn as compared with the average for the forty-year period, and the average for the whole country fell 5 bushels below the normal for the period.

DROUGHTS OF 1894 AND 1895.

Professor Henry, in Climatology of the United States, says:

The greatest drought this country has experienced in the past 100 years, both as to its intensity and the extent of territory covered, culminated in the middle Mississippi and Missouri valleys in 1894, and in the Lake region and Atlantic coast districts in 1895.

DEFICIENT RAINFALL IN 1893.

The drought of 1894 was the culmination of a period of deficient rainfall and high temperatures that began during the early summer of 1893.

DROUGHT OF 1894.

The seasonal rainfall from March 1 to October 1 was largely deficient from the Missouri Valley eastward to the Atlantic, including the coast States from the Carolinas northward. A marked deficiency also occurred in the Central Gulf States and California. The seasonal deficiency in rainfall exceeded 10 inches in portions of New England and the Middle Atlantic States, eastern Florida, on the central Gulf coast, eastern Tennessee, and from the Ohio Valley northward over the central Mississippi and Missouri valleys. In but one week, from April 30 to September 10, did the rainfall for Huron, S. Dak., which is in the region of severe drought, exceed the weekly average at that station, while the temperature was above the normal throughout almost the whole of the same period. While the actual deficiency in rainfall of 12 inches in central Iowa was equaled or exceeded in portions of Florida and eastern Tennessee, in no other section of the country east of the Rocky Mountains did the seasonal rainfall form so small a percentage of the normal amount as in Iowa and the eastern portions of Nebraska and South Dakota, where the actual rainfall was only about 50 per cent of the usual seasonal amount, although portions of New England, the Middle Atlantic States, and eastern Tennessee received less than 60 per cent of the seasonal rainfall.

The extensive and protracted drought of July and August was very injurious to crops, most seriously affecting the corn crop, the principal corn-producing States being covered by the regiou of severest drought.

Rains of April were general deficient in almost all parts of the country, except northern Pacific coast, upper Missouri Valley, and upper Mississippi Valley, although the deficiency east of the Mississippi was not especially marked except along the south Atlantic coast.

In May the greatest deficiency in precipitation, 3 inches or more, occurred in the States of South Dakota, Nebraska, Kansas, Iowa, Illinois, and Missouri.

In June, July, aud August the drought continued unabated in these States and extended into the upper Missouri and Ohio valleys, the Lake region, and portions of New England and Middle Atlantic States. The months of July and August were exceptionally dry in the Ohio Valley, Lake region, Missouri Valley, and middle and upper portions of the Mississippi Valley. Over this great area less than 2 inches of rain, on the average, fell in two months. In Iowa the average precipitation for July was 0.6 inch—3.7 iuches below the normal; in August, 1.6 iuches—2 inches below normal. The rainfall of September was not far from normal in the drought-stricken region of the Middle West, but continued below normal in a number of other districts.

DROUGHT OF 1895.

The shortage of rainfall during 1895 was almost as great and as widespread as in the previous year, but the region of greatest intensity was shifted from the middle Mississippi Valley eastward to the Lake region and upper Ohio Valley.[a]

EFFECT OF DROUGHT ON CROP PRODUCTION.

Notwithstanding the widespread deficiency in annual precipitation, the total crop production in the United States for both 1894 and 1895 did not fall greatly below a normal year, except that the corn crop for 1894 and the hay crop for 1895 were both short crops. The average yield per acre for corn in 1894 was 19.4 bushels, as against an average of 23.5 bushels for teu years, 1892–1901.

The corn yield for 1894 was generally below the norual, and was much below it in Kansas, Iowa, aud Nebraska—in the two last the lowest recorded for those States. In both States the precipitatiou for the summer was also the least recorded, while in July the average rainfall for Iowa and eastern Kansas and Nebraska was only about one-half inch. In Iowa, the month of July, 1894, was the driest ever experienced.

According to Mr. J. Warren Smith,[b] of the United States Weather Bureau, the precipitation for 1895 in the great corn States of the Middle West was abundant, and excessive in Missouri and Kansas. An examinatiou of the available statistics fails to show any marked decliue in corn yields in 1895; in fact, the general average for the whole country was above the normal.

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[a] See Climatology of the United States, by A. J. Henry, p. 52. Statistics show, however, that, even in the Lake region and Ohio Valley, the yields were lower for 1894 than for 1895; iu fact, the general average for the whole country in 1895 is above the normal.

[b] See Relation of Precipitation to Yield of Corn, by J. Warren Smith, Yearbook, Dept. of Agr., 1903.

DROUGHTS OF 1894 AND 1895.

Average yield of corn in bushels per acre.

State.	1892.	1893.[a]	1894.	1895.	1896.	Normal.
Maine	35.5	30.3	39.9	42.0	37.0	33.2
New Hampshire	37.8	31.7	34.3	40.2	42.0	35.0
Vermont	38.0	32.4	40.8	45.6	41.0	35.0
Massachusetts	38.7	33.5	34.5	43.9	43.0	34.8
Rhode Island	33.4	24.4	31.4	30.9	34.0	30.4
Connecticut	34.5	28.2	31.0	37.9	38.0	32.5
New York	33.0	29.5	28.2	35.6	34.0	31.0
New Jersey	31.6	25.9	33.1	33.0	33.0	34.2
Pennsylvania	30.5	24.5	32.0	33.5	40.0	33.3
Delaware	18.7	24.6	22.0	21.0	22.0	22.8
Maryland	20.6	24.2	22.9	26.8	32.0	26.7
Virginia	15.3	18.9	19.1	18.6	21.5	19.2
North Carolina	10.2	12.3	13.4	14.5	12.0	13.5
South Carolina	10.5	7.7	11.2	11.1	9.0	9.7
Georgia	11.2	11.1	11.7	13.3	11.0	11.0
Florida	9.0	9.7	10.1	11.2	10.0	9.9
Alabama	12.2	11.5	13.7	15.9	12.5	13.1
Mi sissippi	13.7	13.1	17.2	15.8	13.5	15.0
Louisiana	14.8	14.2	16.2	18.1	13.0	16.8
Texas	21.4	17.6	19.0	26.4	9.5	20.0
West Virginia	22.5	21.7	18.5	24.2	30.0	25.9
Ohio	29.4	23.8	26.3	32.6	41.0	33.0
Indiana	29.3	24.7	28.9	32.8	35.0	31.4
Illinois	26.2	25.7	28.8	37.4	40.5	30.3
Kentucky	23.3	23.5	23.0	31.2	28.0	26.4
Tennessee	20.3	21.3	21.9	25.0	23.0	22.1
Arkansas	17.5	16.2	19.2	21.5	13.5	21.0
Michigan	25.0	23.7	23.2	33.8	38.0	30.8
Wisconsin	27.3	29.8	20.7	31.8	37.0	31.2
Minnesota	27.0	28.3	18.4	31.2	30.5	30.0
Missouri	27.7	27.9	22.0	36.0	27.0	28.5
Iowa	28.3	33.9	15.0	35.1	39.0	32.4
Kansas	24.5	21.3	11.2	24.3	28.0	27.2
Nebraska	28.2	25.2	6.0	16.1	37.5	30.4
North Dakota	21.4	20.7	19.2	21.3	35.0	22.1
South Dakota	22.3	23.7	4.2	11.1	26.0	23.5
Colorado	22.3	16.5	19.7	20.7	16.0	22.0
Montana	19.4	27.5	32.7	25.0	26.0	24.3
Wyoming	18.5	18.5	30.0	27.5	25.0	24.6
Utah	18.1	21.5	24.4	20.3	25.0	22.5
Idaho	16.8	19.5	28.6	30.7	....	25.1
Washington	18.0	21.3	20.8	17.1	14.0	21.6
Oregon	21.5	24.7	25.4	26.4	22.0	25.5
California	30.3	37.1	19.3	34.5	37.0	31.4
Arizona	17.4	17.8	18.6	26.0	....	21.6
New Mexico	20.0	25.3	19.1	27.2	....	22.0

[a] The drought of 1894 was the culmination of a period of deficient rainfall and high temperatures that began during the early summer of 1893.

WEATHER CONDITIONS FOR 1896 AND 1897.

The corn crop of 1896 was above the average for the country for the 40-year period. Available data show that for the greater part of the corn belt abundant rains prevailed, with the exception that in the Western Gulf States the precipitation for the whole year was 12.5 inches below the normal rainfall, and in the South Atlantic States it was 10.7 inches below.[a]

In 1897 droughty conditions prevailed over portions of Texas, Arkansas, Missouri, Tennessee, Kansas, Louisiana, Virginia, Kentucky, and North Carolina. Cool weather and frosts during the early summer seriously injured corn in Wisconsin, Minnesota, and North Dakota.

[a] See Rainfall of the Crop Season, by A. J. Henry, Yearbook, Dept. of Agr., 1897, p. 616.

Average yield of corn in bushels per acre.

State.	1896.	1897.	Normal.
Virginia	21.5	18.0	19.2
North Carolina	12.0	13.0	13.5
South Carolina	9.0	9.0	9.7
Florida	10.0	8.0	9.9
Louisiana	13.0	17.0	16.8
Texas	9.5	18.5	20.6
Arkansas	13.5	16.0	21.0
Kentucky	28.0	23.0	26.4
Tennessee	23.0	21.0	22.1
Kansas	28.0	18.0	27.2
Missouri	27.0	26.0	28.5
Wisconsin	37.0	33.0	31.2
Minnesota	30.5	26.0	30.0
North Dakota	35.0	17.0	22.1

WEATHER CONDITIONS FOR 1898.

On the whole the season was generally favorable for corn.

Severe local droughts occurred in California from about April 1 to May 15 (interrupted with slight rainfall in the southern portion during the week ending May 2). Excessive heat and drought occurred during the latter half of August in parts of Nebraska, Kansas, Missouri, and generally in the States of the eastern Rocky Mountain slope.

LOCAL DROUGHT OF 1899.

Season generally very favorable for corn. Late corn was injured considerably by drought, which prevailed from about August 10 for two weeks in parts of Missouri, Kansas, and Nebraska, and from about August 20 for three to four weeks over the greater part of Oklahoma, Texas, southern Missouri, and States of the central Mississippi and Ohio valleys.

A glance at the following figures will show the effect of the drought:

Average yield of corn in bushels per acre.

State.	1899.	Normal.	State.	1899.	Normal
Kentucky	21.0	26.4	Missouri	26.0	28.5
Tennessee	20.0	22.1	Kansas	27.0	27.2
Arkansas	20.0	21.0	Nebraska	28.0	30.4
Oklahoma	19.0	23.5	Michigan	25.0	30.8
Texas	18.0	20.0	Iowa	31.0	32.4

LOCAL DROUGHT OF 1900.

The Weather Bureau reports the year for the country as a whole as a good corn year.

A condition of drought occurred from about May 7 to July 1, with intermittent periods of very slight rainfall, in portions of the upper Missouri Valley. The droughty conditions were reported to be especially severe in eastern Montana and North Dakota, and the following figures, so far as corn crop is concerned, show the influence of the dry weather in these States:

Average yield of corn in bushels per acre.

State.	1900.	Normal.
North Dakota	16.0	22.6
Montana	15.0	25.0

DROUGHT OF 1901.

A severe drought occurred in 1901, which cut the corn crop very short.

This drought prevailed from June 24 to July 29—thirty-six days—over the States of the central valleys and middle Rocky Mountain region, and also in lesser degree in the Lake region, the Ohio Valley, and Tennessee.

After July 29 rains occurred over the larger part of the drought area of the Mississippi and upper Missouri valleys, but drought continued about a week longer, becoming very serious in the Ohio Valley and Tennessee.

Average yield of corn in bushels per acre.

State.	1900.	1901.	1902.	Normal.
West Virginia	27.0	23.0	26.5	25.9
Ohio	37.0	26.1	38.0	33.0
Indiana	38.0	19.8	37.9	31.4
Illinois	37.0	21.4	38.7	30.3
Wisconsin	40.0	27.4	28.2	31.2
Minnesota	33.0	26.3	22.8	30.0
Iowa	38.0	25.0	32.0	32.4
Missouri	28.0	10.1	39.0	28.5
South Dakota	27.0	21.0	18.9	23.5
Nebraska	26.0	14.1	32.3	30.4
Kansas	19.0	7.8	29.9	27.2
Colorado	19.0	17.1	16.5	22.0
Kentucky	26.0	15.6	27.0	26.4
Tennessee	20.0	14.2	21.9	22.1
Mississippi	11.0	10.9	11.5	15.0
Louisiana	17.0	13.7	12.5	16.8
Texas	18.0	11.6	8.1	20.0
Oklahoma	26.0	7.3	25.8	23.5
Arkansas	19.0	8.1	21.3	21.0
Indian Territory	....	12.0	24.9	27.2

The average yield for the whole country this year was only 16.7 bushels per acre, which is the lowest average yield reported for the United States since 1867.

WEATHER CONDITIONS FOR 1902.

A drought of several weeks' duration prevailed over the Gulf States during June and July. A severe drought also occurred over the central and southern Rocky Mountain districts from July 25 to September 20.

The season was characterized, however, in the greater portion of the corn belt by excessive rains and unusually cold weather, especially over the central and northern portions of the belt and in the New England States. Cold weather also prevailed in the northern and central Rocky Mountain regions. Killing frosts occurred in New England and in the Lake regions in June; late corn was seriously damaged by heavy frosts over the northern part of the corn belt, especially west of the Mississippi River, frost with ice occurring as early as August 29 in exposed places in the northern Rocky Mountain region.

While the yield for the entire country was slightly above the normal, it may be seen from the following figures that the cold weather was responsible for very reduced yields of corn in a number of States. In the Gulf States, however, i. e., Alabama, Mississippi, Louisiana, and Texas, the low yields were undoubtedly due to drought.

Average yield of corn in bushels per acre.

State.	1902.	Normal.
Maine	21.7	33.2
New Hampshire	23.3	35.0
Vermont	21.8	35.0
Massachusetts	31.3	34.8
Rhode Island	28.4	30.4
Connecticut	31.5	32.5
New York	25.0	31.0
Michigan	26.4	30.8
Wisconsin	28.2	31.2
Minnesota	22.8	30.0
Iowa	32.0	32.4
North Dakota	19.4	22.1
South Dakota	18.9	23.5
Colorado	16.5	22.0
Wyoming	19.8	24.6
Alabama	8.4	13.1
Mississippi	11.5	15.0
Louisiana	12.5	16.8
Texas	8.1	20.0

WEATHER CONDITIONS FOR 1903.

May 4.—This week was unseasonably cool over much the greater part of the country, the minimum temperatures on April 30 and May 1 and 2 being the lowest recorded in the last thirty years at nearly all Weather Bureau stations from the central and west Gulf coasts to the upper Missouri Valley, and also at a number of stations in the central Mississippi and Ohio valleys, Lake region, and New England. Unseasonably low temperatures checked the growth of all vegetation, and heavy frosts and freezes caused much damage. * * * The early planted corn was extensively killed by the freeze during the latter part of the week in Missouri, Kansas, Oklahoma, and Texas, and the crop suffered from cold weather throughout the Southern States.

After the early freeze corn was generally replanted in the Southern States and Gulf States, and the remainder of the season was generally favorable for corn in these sections, where average crops were obtained. Replanting was also necessary in many other sections where early corn had been planted.

The whole crop season was abnormally cool over the Missouri and upper Mississippi valleys, and much corn was seriously damaged by excessive rains.

Drought occurred from May 15 to about June 15 in the northern portion of the Middle Atlantic States and in the New England States. The droughty conditions in the Middle Atlantic States were reported to be especially severe in eastern New York.

Average yield of corn in bushels per acre.

State.	1902.	1903.	1904.	Normal.
Maine	21.7	30.2	39.7	33.2
New Hampshire	23.3	21.0	27.3	35.0
Vermont	21.8	23.4	35.9	35.0
Massachusetts	31.3	24.0	36.0	34.8
Rhode Island	28.4	30.1	34.1	30.4
Connecticut	31.5	22.4	38.9	32.5
New York	25.0	25.0	27.3	31.0
New Jersey	34.5	24.0	38.0	34.2
Pennsylvania	36.1	31.2	34.0	33.3
West Virginia	26.5	22.6	25.3	25.9
Wisconsin	28.2	29.3	29.7	31.2
Minnesota	22.8	28.3	26.9	30.0
Iowa	32.0	28.0	32.6	32.4
Nebraska	32.3	26.0	32.8	30.4
Kansas	29.9	25.6	20.9	27.2

WEATHER CONDITIONS FOR 1904.

The season was generally cool and rainy over the greater part of the corn belt.

A three-weeks' drought prevailed during May over the east Gulf States, but was not serious enough to cause any reduction in the yield of corn, good average crops being secured in these States.

The cool weather, rains, lack of sunshine, and lack of cultivation were probably responsible for a decline in yield in several of the States.

Average yield of corn in bushels per acre.

State.	1903.	1904.	1905.	Normal.
New York	25.0	27.3	31.5	31.0
Michigan	33.5	28.6	34.0	30.8
Minnesota	28.3	26.9	32.5	30.0
Missouri	32.4	26.2	33.8	28.5
North Dakota	25.2	21.2	27.5	22.1
Kansas	25.6	20.9	27.7	27.2
Montana	24.1	22.2	19.4	24.3

WEATHER CONDITIONS FOR 1905.

The season in general was very favorable for corn.

Planting was delayed by cold weather and rain, which continued as late as June 1 and was general throughout the corn belt. Germination was slow and corn suffered from lack of cultivation.

Some damage was done to corn as a result of rains and high winds in the lower Missouri Valley, especially in Kansas and Missouri. In Missouri corn was extensively blown down, but the yield was heavy notwithstanding this. Wind also did considerable injury in Nebraska, Arkansas, and Ohio.

No serious droughts.

The yield was about average in all States except Montana, Oregon, Louisiana, and Arkansas; in many States considerably above the average.

WEATHER CONDITIONS FOR 1906.

The conditions over the country were generally favorable for corn, but local droughts prevailed over portions of the West Gulf States, the lower Mississippi Valley, and portions of Missouri and Tennessee during the week ending May 14 and for two weeks in June.

With the exception of Montana, however, every State in the Union yielded crops above the normal for the forty-year period, the average for the whole country being higher than for any year since 1872.

STATISTICS OF CORN.

Average yield of corn in the United States, in bushels per acre, for the forty years 1867–1906.

(Marked decreases in yield, as compared with the average for the forty-year period, are indicated by italic and boldface figures. Italic figures show decreased yields due principally to severe local or sectional droughts. Boldface figures show the low yields due to the great general droughts.)

Year.	Maine.	New Hampshire.	Vermont.	Massachusetts.	Rhode Island.	Connecticut.	New York.	New Jersey.	Pennsylvania.	Delaware.	Maryland.	Virginia.	West Virginia.	North Carolina.	South Carolina.	Georgia.	Florida.
1867	33.4	35.5	36.2	35.7	25.7	33.0	30.4	33.1	32.0	*16.3*	28.4	20.9	29.7	11.6	9.6	13.1	11.8
1868	29.8	35.0	38.5	37.0	27.0	34.0	32.0	37.5	35.0	25.0	27.7	19.3	35.0	14.3	10.2	12.7	10.5
1869	24.3	30.0	34.0	34.2	25.2	31.2	27.1	30.8	31.4	18.0	20.2	*15.5*	27.8	14.8	11.6	11.0	11.2
1870	33.0	36.5	39.6	33.0	26.0	*26.4*	34.0	33.0	35.8	25.0	22.5	20.0	30.4	14.6	8.9	13.5	10.8
1871	27.2	35.7	35.6	34.3	27.3	31.4	33.0	36.0	35.5	22.0	23.6	22.6	27.6	14.0	10.0	10.3	10.7
1872	33.5	38.2	39.0	34.0	30.0	31.2	37.5	39.5	39.0	20.0	23.0	21.0	28.5	16.0	10.5	12.5	9.6
1873	24.0	37.5	31.0	35.0	28.7	30.0	31.0	36.0	35.1	19.0	21.4	19.0	29.0	14.2	9.5	12.3	10.4
1874	24.6	36.4	36.1	32.0	24.3	30.0	30.0	35.0	33.2	18.0	20.5	20.0	26.5	16.4	11.0	11.1	10.6
1875	30.5	38.0	37.0	37.0	27.5	29.0	34.0	41.0	40.0	26.0	30.0	22.0	29.1	15.0	10.2	10.0	10.0
1876	31.0	42.0	39.0	35.0	35.0	32.5	30.0	36.0	35.0	30.0	29.0	20.0	28.2	14.6	8.2	11.0	10.0
1877	36.0	42.5	39.0	34.7	33.0	29.0	32.0	36.4	33.0	22.0	28.0	19.6	25.5	14.0	9.0	10.5	12.9
1878	40.0	39.0	41.0	36.0	32.0	29.6	36.0	36.0	35.0	25.0	23.5	17.5	27.2	13.6	9.3	11.0	9.0
1879	30.0	32.5	36.0	36.0	32.0	29.0	33.0	34.0	35.0	27.0	30.6	19.0	31.0	15.0	*7.5*	9.3	*8.5*
1880	35.4	38.0	32.0	33.5	30.0	29.0	34.8	41.0	40.6	32.0	32.0	25.0	30.0	16.4	9.3	9.2	9.4
1881	34.0	34.2	35.7	25.1	27.0	**25.5**	**26.4**	**23.2**	**25.2**	**14.4**	24.2	**15.0**	22.7	11.7	**6.7**	**8.3**	**8.3**
1882	29.2	*23.4*	33.9	*21.7*	*23.0*	*20.1*	27.5	28.9	31.3	18.9	25.9	19.1	25.4	14.0	12.0	13.3	9.5
1883	35.0	36.0	31.0	35.0	32.0	30.0	*23.0*	28.0	27.0	18.0	23.5	*14.0*	24.3	11.5	*8.0*	*8.7*	*8.5*
1884	34.7	33.2	33.2	34.0	30.4	31.0	30.1	32.0	31.0	18.5	21.8	15.2	*20.0*	12.5	9.2	10.8	9.5
1885	32.3	33.8	32.2	34.0	33.5	35.0	30.7	32.0	32.5	19.3	22.0	*14.9*	23.8	*9.9*	9.0	11.3	9.0
1886	31.4	35.4	32.8	32.7	31.5	34.3	31.3	27.2	28.2	*16.6*	20.9	15.5	22.8	*10.5*	9.1	10.8	10.4
1887	35.2	34.3	35.5	35.4	32.0	34.0	33.0	30.0	32.2	20.0	27.0	17.5	**19.0**	13.4	10.0	11.0	10.6
1888	*19.3*	*22.6*	*24.3*	30.1	30.4	31.2	32.4	32.4	32.5	*17.4*	23.7	16.3	23.8	*10.6*	8.7	9.6	9.8
1889	36.0	36.5	35.0	34.3	31.3	31.0	29.3	30.2	29.8	*17.5*	20.6	15.9	22.4	12.0	11.5	11.2	10.7
1890	36.2	36.5	33.5	34.5	32.7	35.7	26.6	31.3	27.5	18.5	22.5	17.5	**20.0**	13.3	10.2	10.5	9.3
1891	37.5	35.8	37.2	39.5	34.5	36.0	31.8	34.2	33.3	22.0	25.5	19.7	27.3	14.1	11.6	12.2	11.0
1892	35.5	37.8	38.0	38.7	33.4	34.5	33.0	31.6	30.5	18.7	20.6	15.3	22.5	*10.2*	10.5	11.2	9.0
1893	30.3	31.7	32.4	33.5	*24.4*	28.2	29.5	*25.9*	*24.5*	24.6	24.2	18.9	21.7	12.3	7.7	11.1	9.7
1894	39.9	34.3	40.8	34.5	31.4	31.0	28.2	33.1	32.0	22.0	22.9	19.1	**18.5**	13.4	11.2	11.7	10.1
1895	42.0	40.2	45.6	43.9	30.9	37.9	35.6	33.0	33.5	21.0	26.8	18.6	24.2	14.5	11.1	13.0	11.2
1896	37.0	42.0	41.0	43.0	34.0	38.0	34.0	33.0	40.0	22.0	32.0	21.5	30.0	12.0	9.0	11.0	10.0
1897	37.0	34.0	35.0	32.5	31.0	31.5	31.0	31.5	36.0	29 0	33.0	18.0	24.5	13.0	9.0	11.0	*8.0*
1898	40.0	41.0	43.0	40.0	34.0	37.0	33.0	37.0	37.0	25.0	31.0	22.0	29.0	14.0	10.0	9.0	9.0
1899	36.0	39.0	36.0	36.0	31.0	39.0	31.0	39.0	32.0	22.0	32.0	20.0	26.0	13.0	9.0	10.0	10.0
1900	36.0	37.0	40.0	38.0	32.0	38.0	32.0	33.0	*25.0*	24.0	26.0	16.0	27.0	12.0	7.0	10.0	*8.0*
1901	39.4	38.5	40.0	40.5	32.1	39.0	33.0	36.9	35.0	30.0	34.2	22.2	23.0	12.0	**6.9**	10.0	9.0
1902	*21.7*	*23.3*	*21.8*	31.3	28.4	31.5	*25.0*	34.5	36.1	28.0	32.4	22.0	26.5	13.9	10.4	9.0	8.6
1903	30.2	*21.0*	*23.4*	*24.0*	30.1	*22.4*	*25.0*	*24.0*	31.2	27.5	28.7	21.8	22.6	14.7	10.3	11.7	9.9
1904	39.7	27.3	35.9	36.0	34.1	38.9	27.3	38.0	34.0	30.4	33.4	23.3	25.3	15.2	12.4	11.9	10.7
1905	34.3	37.0	34.7	37.5	32.5	42.7	31.5	35.8	38.9	30.4	36.9	23.4	29.8	13.9	10.9	11.0	10.1
1906	37.0	37.5	35.5	39.7	33.1	40.0	34.9	36.3	40.2	30.0	35.0	24.3	30.3	15.3	12.2	12.0	11.0
Average	33.2	35.0	35.0	34.8	30.4	32.5	31.0	34.2	33.3	22.8	26.7	19.2	25.9	13.5	9.7	11.0	9.9

Average yield of corn in the United States, etc.—Continued.

Year	Ohio.	Indiana.	Illinois.	Michigan.	Wisconsin.	Minnesota.	Iowa.	Missouri	Nebraska.	Kansas.	Dakota.	North Dakota.	South Dakota.	Kentucky.	Tennessee.	Alabama.	Mississippi.
1867	28.7	29.2	*23.8*	31.4	33.6	30.0	33.8	27.2	36.0	38.6	....	....	....	24.7	23.7	16.2	15.7
1868	34.0	34.0	34.2	33.0	33.0	33.5	37.0	30.3	*22.9*	*18.0*	....	....	....	32.7	25.3	*10.8*	17.1
1869	30.1	*23.2*	*23.2*	28.9	26.4	29.1	33.2	30.6	42.2	48.4	....	....	....	25.0	20.0	15.0	17.5
1870	39.0	39.5	35.2	37.0	38.0	33.0	32.0	31.4	29.9	28.0	....	....	....	32.1	25.8	17.5	16.5
1871	38.5	35.7	38.3	32.4	37.7	37.3	42.5	38.0	41.5	40.0	....	....	....	27.3	23.0	14.5	14.0
1872	39.5	38.7	39.8	36.0	38.0	35.2	39.8	37.0	37.8	38.5	....	....	....	31.2	23.5	17.6	17.5
1873	35.0	25.6	*21.0*	31.0	30.0	31.5	29.0	*23.5*	35.0	39.1	....	....	....	29.5	22.5	14.5	15.5
1874	36.0	27.0	**18.0**	27.0	28.2	31.0	29.2	**16.0**	**10.0**	**10.5**	....	....	....	25.0	**16.8**	12.3	13.8
1875	34.5	34.0	34.3	33.0	*21.0*	29.2	35.0	36.6	40.0	40.0	....	....	....	33.3	26.5	12.6	18.0
1876	36.7	30.0	*25.0*	29.0	34.0	*25.4*	30.0	27.8	30.0	43.5	....	....	....	33.5	24.5	13.0	15.0
1877	31.5	30.0	29.0	31.0	28.0	29.0	32.5	29.0	38.0	36.5	....	....	....	30.3	25.0	12.0	15.0
1878	34.9	32.8	27.1	37.4	37.5	38.1	37.4	26.2	42.0	33.9	....	....	....	22.7	19.3	12.0	13.0
1879	35.0	33.0	35.0	37.0	39.0	35.0	38.0	37.0	41.0	33.0	....	....	....	32.0	25.0	13.0	16.0
1880	37.5	29.0	27.2	40.7	33.0	35.0	38.0	28.4	31.0	29.3	....	....	....	29.1	22.4	12.4	14.6
1881	**25.4**	**21.8**	**19.4**	28.0	27.6	32.0	**25.8**	**16.5**	27.4	**18.2**	....	....	....	**17.0**	**12.4**	**9.9**	**11.0**
1882	31.3	31.3	*23.0*	30.7	28.8	32.0	*25.9*	29.5	34.9	33.7	25.0	....	....	24.3	24.1	13.9	16.8
1883	*26.1*	27.0	*25.0*	*23.5*	*21.0*	*20.8*	*24.3*	27.5	36.0	36.7	*18.2*	....	....	24.0	20.0	11.5	13.5
1884	30.0	29.0	30.0	28.0	*24.6*	33.5	34.5	33.0	37.7	36.9	30.0	....	....	22.1	20.3	13.0	13.5
1885	37.1	35.5	31.4	32.7	30.1	28.4	32.1	31.3	36.7	32.4	28.9	....	....	25.5	21.2	13.4	13.4
1886	32.2	31.9	*24.5*	29.1	*25.7*	29.8	*25.1*	*22.2*	27.4	*21.8*	23.9	....	....	25.2	20.7	12.1	13.1
1887	**26.3**	**20.0**	**19.2**	**22.5**	**25.3**	29.8	**25.5**	**22.0**	**24.1**	**14.6**	33.0	....	....	**18.3**	21.5	13.6	17.3
1888	32.5	34.8	35.7	30.0	30.6	29.3	35.8	31.0	35.2	26.7	25.5	....	....	25.8	20.8	12.7	14.7
1889	29.6	29 0	32.3	*23.5*	26.3	28.5	39.5	32.2	36.5	35.3	*18.0*	....	....	26.5	22.0	13.5	14.8
1890	**23.5**	**24.7**	26.2	26.7	30.0	27.7	**26.0**	25.8	**18.0**	**15.6**	**13.6**	....	....	**22.6**	**18.8**	**10.2**	12,5
1891	32.0	33.3	33.5	29.5	26.7	26.5	36.7	29.9	35.2	26.7	....	18.0	22.5	30.0	22.7	12.7	15.2
1892	29.4	29.3	26.2	25.0	27.3	27.0	28.3	27.7	28.2	24.5	....	21.4	22.3	23.3	20.3	12.2	13.7
1893	*23.8*	*24.7*	25.7	*23.7*	29.8	28.3	33.9	27.9	25.2	*21.3*	....	20.7	23.7	23.5	21.3	11.5	13.1
1894	**26.3**	28.9	28.8	**23.2**	**20.7**	**18.4**	**15.0**	**22.0**	**6.0**	**11.2**	....	19.2	**4.2**	23.0	21.9	13.7	17.2
1895	32.6	32.8	37.4	33.8	31.8	31.2	35.1	36.0	*16.1*	24.3	....	21.3	11.1	31.2	25.0	15.9	15.8
1896	41.0	35.0	40.5	38.0	37.0	30.5	39.0	27.0	37.5	28.0	....	35.0	26.0	28.0	23.0	12.5	13.5
1897	32.5	30.0	32.5	31.5	33.0	26.0	29.0	26.0	30.0	*18.0*	....	17.0	24.0	23.0	21.0	12.0	14.5
1898	37.0	36.0	30.0	34.0	35.0	32.0	35.0	26.0	*21.0*	*16.0*	....	19.0	28.0	31.0	26.0	15.0	18.0
1899	36.0	38.0	36.0	25.0	35.0	33.0	31.0	26.0	28.0	27.0	....	23.0	26.0	*21.0*	20.0	12.0	16.0
1900	37.0	38.0	37.0	36.0	40.0	33.0	38.0	28.0	26.0	*19.0*	....	*16.0*	27.0	26.0	20.0	11.0	*11.0*
1901	**26.1**	**19.8**	**21.4**	34.5	27.4	26.3	**25.0**	**10.1**	**14.1**	**7.8**	....	22.6	21.0	**15.6**	**14.2**	**10.9**	**10.9**
1902	38.0	37.9	38.7	*26.4*	28.2	*22.8*	32.0	39.0	32.3	29.9	....	19.4	18.9	27.0	21.9	*8.4*	*11.5*
1903	29.6	33.2	32.2	33.5	29.3	28.3	28.0	32.4	26.0	25.6	....	25.2	27.2	26.6	23.5	14.8	18.4
1904	32.5	31.5	36.5	28.6	29.7	26.9	32.6	26.2	32.8	*20.9*	....	21.2	28.1	26.9	25.0	15.0	19.1
1905	37.8	40.7	39.8	34.0	37.6	32.5	34.8	33.8	32.8	27.7	....	27.5	31.8	29.7	24.6	14.8	14.3
1906	42.6	39.6	36.1	37.0	41.2	33.6	39.5	32.3	34.1	28.9	....	27.8	33.5	33.0	28.1	16.0	18.5
Average	33.0	31.4	30.3	30.8	31.2	30.0	32.4	28.5	30.4	27.2	24.0	22.1	23.5	26.4	22.1	13.1	15.0

Average yield of corn in the United States, etc.—Continued.

Year.	Louisiana.	Texas.	Arkansas.	Indian Territory.	Oklahoma.	California.	Oregon.	Washington.	Colorado.	Wyoming.	Montana.	Utah.	Idaho.	New Mexico.	Arizona.	Nevada.	United States.
1867	15.6	28.2	26.5	....	....	....	....	....	....	....	....	....	....	....	....	....	23.6
1868	22.0	25.0	30.5	....	....	45.0	....	....	....	....	....	....	....	....	....	....	26.0
1869	25.0	29.0	28.0	....	....	41.4	....	....	....	....	....	....	....	....	....	....	23.6
1870	22.5	26.5	31.8	....	....	35.6	29.7	....	....	....	....	....	....	....	....	35.0	28.3
1871	14.4	19.0	26.7	....	....	38.0	26.6	....	....	....	....	....	....	....	....	32.0	29.1
1872	18.5	25.3	23.5	....	....	35.0	28.0	....	....	....	....	....	....	....	....	33.0	30.8
1873	16.5	19.0	23.5	....	....	41.0	30.0	....	....	....	....	....	....	....	....	30.0	36.2
1874	15.5	19.0	**12.6**	....	....	29.0	30.5	....	....	....	....	....	....	....	....	29.0	**20.7**
1875	15.5	20.0	30.0	....	....	36.3	26.5	....	....	....	....	....	....	....	....	29.0	29.5
1876	17.2	25.0	24.0	....	....	33.0	30.0	....	....	....	....	....	....	....	....	28.0	26.2
1877	17.0	24.0	24.0	....	....	30.0	26.0	....	....	....	....	....	....	....	....	....	26.7
1878	19.9	26.0	24.0	....	....	34.5	33.3	....	....	....	....	....	....	....	....	....	26.9
1879	15.0	*13.0*	24.0	....	....	28.0	32.0	....	....	....	....	....	....	....	....	....	29.2
1880	19.0	25.0	25.0	....	....	32.0	23.3	....	18.5	....	....	....	....	....	....	*20.0*	27.6
1881	**13.0**	**11.9**	**14.8**	....	....	27.2	**20.2**	....	25.5	....	....	....	....	....	....	24.8	**18.6**
1882	18.5	19.3	21.6	....	....	28.3	23.9	23.4	20.0	....	36.6	20.8	28.5	21.2	21.0	*21.7*	24.6
1883	14.2	17.5	17.5	....	....	24.5	23.5	23.0	25.0	....	20.0	21.0	20.0	20.0	20.0	24.9	22.7
1884	*12.7*	16.1	18.5	....	....	30.0	27.8	32.7	28.1	....	24.9	21.7	20.0	20.1	21.2	25.3	25.8
1885	16.8	20.6	20.2	....	....	*24.7*	22.8	26.4	34.5	....	25.0	29.8	21.5	20.5	22.1	24.8	26.5
1886	15.6	*15.7*	20.4	....	....	27.2	26.7	26.1	31.5	....	24.7	20.0	21.5	20.0	22.2	25.7	22.0
1887	18.0	17.0	20.0	....	....	30.0	27.3	21.9	30.0	....	27.5	21.6	28.2	19.0	19.0	27.8	**20.1**
1888	14.8	19.2	19.5	....	....	27.8	22.5	20.0	22.6	....	....	*14.5*	....	18.5	....	....	26.3
1889	17.5	18.3	20.0	....	....	28.2	*20.0*	....	25.4	....	....	18.3	....	20.0	....	....	27.0
1890	16.0	**15.5**	**16.7**	....	....	27.5	21.6	....	18.2	....	....	21.0	....	20.0	....	....	**20.7**
1891	17.3	19.5	21.2	....	....	34.5	27.0	....	21.5	....	....	19.0	....	18.3	....	....	27.0
1892	14.8	21.4	17.5	....	....	30.3	21.5	18.0	22.3	*18.5*	*19.4*	18.1	*16.8*	20.0	17.4	....	23.1
1893	14.2	17.6	*16.2*	....	....	37.1	24.7	21.3	*16.5*	*18.5*	27.5	21.5	19.5	25.3	17.8	....	22.5
1894	16.2	19.0	19.2	....	....	**19.3**	25.4	20.8	19.7	30.0	32.7	24.4	28.6	19.1	18.6	....	**19.4**
1895	18.1	26.4	21.5	....	....	34.5	26.4	17.1	20.7	27.5	25.0	20.3	30.7	27.2	26.0	....	26.2
1896	13.0	*9.5*	*13.5*	....	....	37.0	22.0	*14.0*	*16.0*	25.0	26.0	25.0	....	*16.0*	....	....	28.2
1897	17.0	18.5	*16.0*	....	....	31.5	25.0	18.0	19.0	*12.0*	*18.0*	22.0	....	27.0	....	....	23.8
1898	18.0	25.0	20.0	....	....	26.0	24.0	*12.0*	18.0	*16.0*	28.0	21.0	....	21.0	....	....	24.8
1899	18.0	18.0	20.0	....	19.0	27.0	22.0	23.0	*17.0*	22.0	23.0	20.0	....	20.0	....	....	25.3
1900	17.0	18.0	19.0	....	26.0	25.0	23.0	20.0	19.0	34.0	*15.0*	20.0	....	22.0	....	....	25.3
1901	13.7	**11.6**	**8.1**	**12.0**	**7.3**	31.0	**20.8**	17.5	**17.1**	39.5	25.0	19.4	23.0	31.6	18.0	....	**16.7**
1902	*12.5*	*8.1*	21.3	24.9	25.8	30.5	23.4	23.0	*16.5*	19.8	22.0	20.1	24.7	22.0	20.2	....	26.8
1903	20.6	24.2	20.9	27.7	23.3	30.7	25.8	23.1	19.8	19.4	24.1	21.4	34.5	24.0	22.4	....	25.5
1904	19.9	22.6	21.6	32.4	28.1	28.6	28.8	24.7	20.5	32.5	22.2	33.2	29.3	22.7	23.8	....	26.8
1905	13.7	21.3	17.3	32.7	25.3	32.0	23.0	24.2	23.8	26.9	*19.4*	36.2	27.2	25.3	27.0	....	28.8
1906	17.2	22.5	23.6	33.6	32.9	34.9	27.6	25.2	27.9	27.0	23.4	32.0	28.3	29.4	29.5	....	30.3
Average	16.8	20.0	21.0	27.2	23.5	31.4	25.5	21.6	22.0	24.6	24.3	22.5	25.1	22.0	21.6	27.4	25.2

The principal drought years covered by the above table, where the condition of minimum rainfall was more or less general throughout the United States, were 1874, 1881, 1887, 1890, 1894, and 1901.

1883.—Notable decreased yields in New York, the South Atlantic States, Ohio Valley, Lake region, Minnesota, and Iowa.

1886.—Severe drought in Kansas, Nebraska, the Dakotas, Iowa, Minnesota, and western Wisconsin.

1890.—Decreased yields in Ohio and Indiana, Iowa, Nebraska, Kansas, Kentucky, Tennessee, Alabama, Arkansas, and Texas, due to a drought of unusual severity in the great corn States; other less notable reductions in yield in other States.

1893.—Decreased yields noted particularly in Rhode Island, New Jersey, Pennsylvania, South Carolina, Ohio, Indiana, Michigan, Kansas, Arkansas, Colorado, and Wyoming. ("The drought of 1894 was the culmination of a period of deficient rainfall and high temperature that began during the early summer of 1893."—A. J. Henry.)

1902.—During June corn suffered from drought in the central and west Gulf States. (Early corn was injured by frost in the Ohio Valley and Lake region, and late corn was seriously damaged by heavy frosts over the northern portion of the corn belt, more especially to the westward of the Mississippi River.)

1903.—Drought prevailed in the northern portion of the Middle Atlantic and the New England States from May 15 to about the middle of June.

CROP PRODUCTION ALONE NOT A MEASURE OF THE CONDITION OF AGRICULTURE.

By Walter T. Swingle,
Bureau of Plant Industry, United States Department of Agriculture.

The question as to whether crop production per acre is increasing or decreasing is of so general a nature as to have little direct relation to the condition or needs of the agriculture of the country as a whole.

A large number of factors will always be found working toward increased production, and a large number toward diminished production. In one region the balance will swing one way; in another region the other way. The general average for the whole country is merely an arithmetical mean and becomes of interest only when a detailed analysis of the facts reveals some general efficient cause for the observed advance or decline.

Agriculture in this country is now passing through a period of rapid changes. In many ways its condition may be compared with that of electrical engineering a quarter of a century ago, when discoveries succeeded each other so rapidly that expensive machinery and equipment were often relegated to the junk heap before the varnish had been dimmed.

The constantly extending applications of science to agriculture are working revolutions in farm practices; great changes are taking place in the crops grown, the methods of culture, and in the handling and disposal of the crop itself. These applications of science to farming, which have assumed importance only during the last twenty-five years, make for increased production and for increased certainty of production.

The demonstration that the leguminous crops enrich the soil in which they grow with nitrogen abstracted from the inexhaustible atmospheric supply has, at a single stroke, solved the problem of a cheap and convenient supply of the most important and most expensive element of plant food and the very one whose exhaustion was greatly feared by leading men of science scarcely a decade ago. The proper utilization of leguminous plants in crop rotations becomes, in the light of this discovery, of absolutely fundamental importance in agriculture. Already production has been greatly increased in many sections of this country through the skillful use of alfalfa, clover, vetches, cowpeas, and others of the beneficent crops of the pulse family.

At the same time, thanks largely to the researches of the investigators connected with state experiment stations, much has been taught the farmer as to the needs of various crops and soils in other elements of plant food besides nitrogen. At the same time the state fertilizer controls have rendered fraud and excessive charges almost impossible. No one familiar with American agriculture, especially in the Eastern States, can deny that vastly increased production has resulted from this work of the state experiment stations in preventing fraud in the sale of artificial fertilizers and in showing how fertilizers can be used to the best advantage.

During the past three decades great progress has been made in recognizing, curing, and preventing plant diseases, the most insidious of the farmer's enemies. Tens of millions are saved annually to the country by the use of up-to-date methods of fighting insect and fungous enemies. In many cases both the pests themselves and the possibility of preventing their injuries were alike unknown two decades ago. Vastly increased production and, what is even more important, increased certainty of production have resulted from this brilliant new arm forged by science for man's protection.

Plant breeding—a branch of applied science having even greater possibilities for aiding the progress of agriculture than plant pathology—is of still more recent birth. General interest in the methods and aims of plant breeding dates back scarcely a decade and, as would be expected, only a tithe of what will be done has as yet been accomplished. Nevertheless, great increases in yield, in uniformity of product, in hardiness, in drought and disease resistance, and in other useful qualities of our principal crop plants have already resulted from the tireless activities of a handful of enthusiastic disciples of the new branch of applied science.

The organized work in the introduction of new and superior varieties of crop plants from all parts of the world is even younger than plant breeding, yet already half a dozen new crops, yielding products whose annual value reaches into tens of millions, testify to the striking utility of this line of work.

The scientific study of the soil and of climatic and cultural needs of the varieties of our principal crop plants has only just begun, but is sure to become of the greatest importance in growing crops with the maximum of efficiency—utilizing plants to the utmost through an intimate knowledge of their strong and weak points—in other words, growing crops by brains. In preventing "booms" that ruin thousands through false ideas as to the needs and limitations of crop plants, great good will be accomplished by life-history investigations. Much progress has been made already in the working out of the merits and demerits of the numerous new varieties of cotton, corn, alfalfa, date palms, and other staple crops that have been placed at the disposal of the experimenter during the past decade through the activities of the plant introducers and plant breeders.

As plant breeding and plant introduction advance, the need becomes more acute for a critical analysis and study of all varieties of crop plants, with a view to growing them in the localities and in the manner they require to secure the maximum yield. These three new branches of agricultural science—plant breeding, plant introduction, and plant life-history investigations—will, developing hand in hand, revolutionize all branches of crop production and ultimately greatly increase the yield per acre and decrease the risk of failure.

Recent investigations in the methods of picking, packing, and shipping perishable crops, especially fruits and vegetables, have decreased the cost and increased the amount of the net yield per acre of these crops. All branches of agriculture have been stimulated by the great advances in transportation facilities, by the extension of the rural free delivery, the discovery and extension of the telephone, the invention of the milk separator, improved farm machinery, and other mechanical aids for the farmer.

In the light of these numerous applications of science to agriculture, most of them of very recent date and most of them potent for good, it would seem an idle question to ask whether crop production is now increasing or diminishing.

As a matter of fact, however, there is a reverse side to the picture, and many powerful factors are at work tending to lessen production.

First of all, there has been a slow but general decline in the fertility of farm lands since the forests were cleared and the prairies broken. Wasteful methods of husbandry have contributed and erosion has been insidiously at work until in some regions the decline in productiveness has become alarming.

This decline of fertility in the older parts of the country has been both emphasized and aggravated by the bringing into culture, during the last forty years, of enormous areas of exuberantly fertile new lands of the Great Plains, which through improved methods of transportation have been enabled to compete successfully with regions thousands of miles away. This sharp competition of virgin soils in the West has in many cases prevented in the East the profitable use of commercial fertilizer in growing the accustomed staple crops, and has forced a complete change of farm practices, often ending in cultivated fields being turned into permanent pastures or wood lots.

Agricultural labor has become poorer, scarcer, and much dearer during the last few decades. The immigration, largely of the country peasantry of northern and western Europe, formerly so abundant as to furnish a steady supply of the best kind of farm labor, has in recent years almost ceased, and the hordes of immigrants now flocking to our shores from eastern and southern Europe are largely from the cities and even when they are peasants are so unfamiliar with our methods of agriculture as to be of little worth as farm hands. As a matter of fact, few seek employment in the country when they reach the New World.

The growth of the great industrial centers has also acted to draw laborers from the country to the mines and mills where wages were higher and where the eight-hour day is possible, the latter something almost impossible for the farmer to grant. There can be no doubt that the increasing scarcity of good farm labor has in many regions led to a considerable decline in production.

The present industrial tendency to form gigantic trusts that control the marketing of commodities, with little regard for supply and demand, has been brought sharply home to the farmer by the success of the beef trust in stifling competition and manipulating the transportation and sale of live stock to its own advantage. Improved methods of farm practice tend to turn as many crops as possible into the more easily transportable form of cattle, hogs, sheep, and other live stock, and the success of the beef trust in controlling prices to the disadvantage of the farmer has greatly impeded the spread of better methods of farming and in many cases led to a direct decline of production.

Finally the most important cause of decline in production and decay in the intellectual tone of many of the older farming communities is the draining off of almost all the brighter minds to the large cities. The wide ramifications of the modern railway, telegraph, express, and other large business enterprises, have enabled them to take on as apprentice the bright country boy at the small station and gradually promote him as he develops, each step away from the country and toward the great city.

Even the state agricultural colleges and universities of some of the great agricultural States have acted practically as great employment agencies run at state expense to get farmers' boys and girls paying positions off the farm.

The bright country boy, tired of the endless chores of the farm, finds that he can be educated to be an electrical engineer, a civil engineer, a printer, an architect, a machine-shop foreman, or in any one of a dozen other professions that appeal to his youthful mind because of the attractiveness and stimulating character of the work and because of the relatively high salaries paid to the best young men shortly after graduating.

The farmer's son is too young (in some institutions he must choose his future career when he is only 15 years old) and too inexperienced to see the drawbacks in such careers—that he usually is a hired man all his life; that his children grow up in the big cities and almost never equal their parents in energy or initiative; that his own health declines, and that cares multiply faster than his salary increases. All this is wrong. Positions in the technical world should be filled largely from the city population that can not under any ordinary circumstances become farmers.

A fair proportion of the brightest minds should be induced to remain on the farm, and to do this every effort should be made to make farm life attractive to the bright boys and girls. It is a great mistake to imagine that mere technical discussion on methods of farm practice, with which the farmer's boy is often more familiar than his instructor, or purely mercenary motives, can hold the boy on the farm. He knows, even if his salaried instructor does not, that the intelligent boy with little or no capital can make much more off the farm than on it—at first.

The remedy lies rather in the study of science, whose recent brilliant applications to agriculture tend to interest the talented youth not only in the direct improvement in crop production, but also in science itself, which he finds to be a fascinating and stimulating mental discipline, at the same time work and recreation, a noble study much broader and much more satisfying than any of the practical applications that may be made to the industries, important and interesting as they are.

Farm life, with its multitudinous contacts with nature, with its intimate relations to the biological and physical sciences, is really the ideal place for the scientific investigator. Already the tendency is being manifested in plant breeding to decentralize and to put on the farm the breeding up of races of the crop plants under the particular environmental surroundings they must endure when grown on a commercial scale. Commercial success has already been attained by plant breeding on the farm. The intellectual interest aroused by the breeding of a new flower, a new berry, or a new and superior strain of corn far exceeds in importance the not inconsiderable money value of such new creations.

Other lines of research can, with great advantage, be moved out to the farm, where research is conducted under the most favorable conditions by persons themselves vitally interested in the problems and thoroughly familiar with the local conditions. In large institutions it is necessary to turn over more and more of the actual work of investigation to assistants, often poorly fitted and but superficially interested in the problem.

Farm research, however, is not merely a remote end devoutly to be hoped for; it exists now, and it is to further it and to work further decentralization of research that private, state, and national effort should be directed. It is true that only a few men are able to undertake the more difficult lines of scientific research, but it is just these few who, living on the farm, will be the leaders of their communities in the improvement of agriculture and the helpers of their neighbors in minor but still vitally important lines of experimentation. It is always the gifted few who are able to look beyond the immediately pressing problems of the day and plan for the future.

To drain the country of its brightest minds in the future as completely as has been done during the past few decades is to invite the complete intellectual decline of the farming class, the entry of rich landowners, and the creation of a servile tenantry, possibly with a resultant increased production per acre, but at what a cost!

To increase the attractiveness of farm life and to add intellectual interest to rural occupations, to encourage with every means at the disposal of the Government the country boy who honestly tries to seek for truth, with the end in view of retaining a fair proportion of the brightest minds on the farm, should be given immediate attention before it is too late. A free, active, and intelligent country population is the backbone of any country, and no increase in wealth, no triumphs in the industries, can permanently offset the loss of the nation's greatest asset.

THE AGRICULTURAL RESOURCES OF THE EASTERN UNITED STATES; THEIR DEVELOPMENT AND CONSERVATION.

By E. C. Chilcott,

Bureau of Plant Industry, U. S. Department of Agriculture.

Within the last few years the idea that the agricultural resources of the United States are being rapidly depleted, and that crop production per acre is rapidly falling off, seems to have met with quite general acceptance. I do not believe that this idea is in accord with either the official statistics furnished by this department and the various state organizations dealing with the subject or with the observations of those who have given the subject the most careful consideration. It is not difficult, however, to see how such an impression might be made upon the mind of the superficial observer, or one who was interested mainly in studying the subject from the viewpoint of the great transportation companies. It is undoubtedly true that there are many farms located in nearly, if not quite, every county of the United States where the production of some one crop has materially decreased within the last decade. It is also probably true that there are many farms where not only one crop, but all of the crops produced have decreased both in aggregate quantity per farm and in yield per acre. But, on the other hand, there is an equal or greater number of farms where an increase both in aggregate production and in yield per acre has been experienced. So that, on the whole, when the entire country is taken into consideration, both the yield per acre and the gross amount produced have been on the increase, not only for the last decade but for the last quarter of a century. It would be manifestly impossible, in an article of this length, to point out the many combinations of causes that have led to the increase or decrease of crops upon farms, either considered individually or grouped by counties or States. I think, however, that a consideration of a few concrete examples that have come under my observation may help to throw light upon the problem.

AGRICULTURAL CONDITIONS IN WESTERN NEW YORK.

Upon paying a visit to a locality in western New York with which I had formerly been very familiar, after an absence of twenty-three years I noted many facts which I believe have a very direct bearing upon the subject under discussion. Among these are the following: I found that many of what had formerly been the richest and most productive farms located within a radius of 12 miles of the city of Buffalo had very materially decreased in agricultural production, although their value, due to their proximity to the city, had considerably increased. An inquiry into the reason for these conditions revealed the fact that in nearly every instance the cause of the decreased production was not due to a decrease in the fertility or productive capacity of the farm, but was on account of the difficulty in obtaining efficient farm laborers at a reasonable price. The cause of this scarcity of farm laborers was generally attributed to the fact that the immense growth of manufactures in the city of Buffalo had served to attract the laborers who were formerly engaged upon farms. These manufacturers paid higher wages than the farmers were able to pay, but, on the other hand, the opportunities for morally and physically healthful surroundings are very much better upon the farm than in those parts of the city occupied by the laborers in the factories. This consideration seems to be generally overlooked by the laboring classes. They consider only the difference in cash wages without any regard to the relative amount of comfort and the welfare of their families in country and in city. I believe that right here is an opportunity for a campaign of education and enlightenment. If the laboring classes in the congested manufacturing centers could be shown the desirability of establishing homes where they could rear and educate their families in a morally and physically healthy environment, where they could have a small piece of land upon which to raise a very considerable portion of the food required by the family, without any expense whatever except the labor of those members of the family not actively engaged as wage-earners, it would seem that there could be found many men, now engaged as laborers in factories, but who had formerly had sufficient experience to enable them to perform the ordinary work on a farm in a satisfactory manner, who would gladly exchange the somewhat higher wages obtainable in the city for the advantages offered by the country.

Another important factor which always has operated and which always will operate to deplete the ranks of farm laborers is the fact that the more progressive among them are constantly becoming themselves landowners. The cheap lands of the West have proved very attractive to this class, and as the western lands have increased in value these people have turned their attention more and more to the relatively cheap but poorer lands of the Eastern States. This movement, of course, should be encouraged rather than discouraged, as many of the very best farmers in this country originally belonged to this class. In fact it may be said that the agricultural development of the Central and Western States is due very largely to men who had formerly been employed as farm laborers, and who by frugality and economy had succeeded in saving enough money to enable them to get a start for themselves where cheap land was obtainable.

The explanation of the seemingly anomalous fact that many of the rich farms of western New York have very considerably increased in value and at the same time have decreased in productivity is probably as follows: Many of these farms have been inherited by their present owners and are looked upon not as investments of so much capital but rather as inheritances that should be retained in the family regardless of the fact that they are not yielding a fair interest on the investment. In other instances, the owners realize that their farms are not profitable investments under existing economic conditions, but they believe that conditions will so change that their farms will eventually prove to be so, and this hope, combined with the sentimental reasons already mentioned, serve to discourage any general tendency to sell this class of farm property. A sufficient amount of real estate transfers is being made in the vicinity of these farms to establish and maintain a market price for land, but in almost every instance the purchasers are either men of wealth from the city, who buy the farms for country homes or as a fad where they may spend the money which they make in other lines of business, or foreigners, mainly Germans, who depend largely upon the members of their own families for supplying the necessary labor for conducting the farms. Very few farmers or successful business men would consider this class of farms a profitable investment where all of the labor must be hired.

Where the changes described in the preceding paragraph have been taking place changes of an entirely different nature have occurred within a few miles. Land much inferior in intrinsic agricultural value and a few miles farther from the city has been bought up within the last twenty-five years at a very low figure by thrifty farmers with small cash capital, but with large and industrious families, who, by the application of improved methods of agriculture, have succeeded in bringing what were considered as "worn-out" farms up to a high state of productivity, with a corresponding increase in the market value of the land. The extension of good roads, built by the State, has been a factor in this development, but by no means the most important one.

Here we have two movements in opposite directions—rich farms, owned by intelligent, well-to-do American farmers, getting richer, but less productive, but still increasing in market value, due to proximity to the city, sentimental considerations and hopes of improved economic conditions, which will eventually convert them into paying investments, and poor farms becoming rich and productive mainly because they had become so poor, and consequently so low in price, that they were attractive investments for a class of farmers who are in a measure independent of the labor difficulties experienced by their richer neighbors.

Both of these classes have shared in the general increase of knowledge of the underlying scientific principles upon which successful agriculture is based, which knowledge has been brought about largely through the investigations carried on by the United States Department of Agriculture and the various state organizations engaged in the enlightenment of the American farmer.

It is probable, however, that as a broad generalization, the extent to which each class has been able to profit by this knowledge has been in inverse proportion to the amount of knowledge acquired and the intellectual capacity of the farmers. Those families which are but slightly in advance in education and in general intelligence of the peasant classes of the Old World, from which they sprang, can more successfully cope with the sociological and economic conditions with which the American farmers of to-day are confronted than can the more highly educated and intelligent class who have acquired many artificial tastes and refinements which make it very distasteful, if not altogether impossible, for them to conform to the simpler requirements of their poorer neighbors. From these and many other considerations I believe it is safe to assume that the problems most urgently demanding solution by the farmers of western New York are economic rather than agricultural in their nature. What they want to know is how to secure efficient farm laborers to enable them to apply what they already know, or can easily learn, concerning agricultural methods rather than an addition to their fund of agricultural knowledge.

Another serious disadvantage at which the farmers of western New York are placed is that with improved transportation facilities they are coming more and more directly in competition with the West in the staple farm products and with the South in truck crops. They also, in common with the farmers of the entire country, lack organization in the marketing of their crops. Here is another profitable field for the Department of Agriculture. If local shipping associations were organized throughout the entire country on substantially the same basis as the truck growers' associations of Long Island and other truck-growing districts, and these local associations organized into a national association, an immense amount of loss to farmers could be prevented and the consumer would not only be able to procure all kinds of farm and garden produce in much more wholesome and attractive condition, but at less cost than at present. It would take some time, much earnest effort, and the expenditure of considerable amounts of money to effect such a national organization, but it could be accomplished, and when well established it would be not only self-supporting but a source of revenue to the stockholders, and it would be able to so control the production, distribution, and marketing of all kinds of farm produce as to prevent overstocking of markets, loss in transit by reason of products being shipped in bad condition, exorbitant commissions and freight charges, and many other evils which now are a heavy tax upon both producer and consumer.

SOME PHASES OF AGRICULTURAL DEVELOPMENT IN THE MIDDLE WEST.

The last quarter of a century has witnessed the passage from the pioneer stage to a fairly stable agricultural state of an immense strip of fertile country extending from the Canadian boundary on the north to the Gulf of Mexico on the south, and from western Minnesota and Iowa, eastern Kansas, Oklahoma, and central Texas on the east, to western North Dakota, South Dakota, Nebraska, Kansas, and western Texas on the west. During this period some rather curious results have been produced in the way of crop yields, both per acre and per farm. At first it would seem that the opening up of a new country like this would result in constantly increasing yields per acre and per farm of all the staple crops, and that any deviation from this rule would indicate soil depletion. Such, however, is not the case. There are thousands of farms within this area which are not producing as much of any of the staple crops as they have produced at some period since they were first opened up, and yet some of these farms are becoming richer rather than poorer, and very few, if any of them, have suffered soil depletion proportionate to the decreased yields.

Probably a majority of the farmers in this area went in debt, if not for the land itself at least for the buildings and equipment. Every effort was then made to obtain the largest and quickest cash return from the farms in order to pay off this indebtedness as soon as possible. In this effort to get out of debt the farmers spared neither themselves, their families, their laborers, their teams, nor their farms. Everything, from the vital energy of the farmer and his family to the fertility of the farm, was converted into dollars to pay off the indebtedness, or to purchase more land, build more and better buildings, or to buy more or better stock. This stage of development usually marked the maximum production of the more bulky and quickly salable products of the farms, but in comparatively few instances was this maximum production maintained for a long term of years. Sooner or later some combination of circumstances would occur to bring about a reaction. This reaction took many different forms, each individual case being controlled by a somewhat different combination of factors, not the least important of which was the personal equation of the farmer and his family; but whatever form it took, in a large majority of cases it resulted in a decreased output of some one or more of the staple farm products. Sometimes the controlling factor was the depletion of the vital energy of the farmer or his wife; sometimes it was the fact that the goal which the farmer had set out to reach was attained, the farm was paid for, the new house or barn was built and paid for, the additional piece of land had been secured, or some other task which had been undertaken was finally finished; sometimes the need of educational and social advantages for the family caused the farmer to move to town, and to let his farm to a tenant who would not maintain the yields at the standard set by the owner; sometimes, and far too often, the pathetic example presents itself of the farmer and his wife who have worked and struggled and suffered privations and worn themselves out in order to provide a farm home where the family could all be together and the children a comfort and support to their declining years, only to find, when all these sacrifies had been made, that the children would abandon them and leave them with a farm on their hands that they were no longer able to manage without help.

In a good many instances farmers have come to the conclusion that the transportation, grain commission, and packing companies have secured such control of the market prices of all farm products that the margin of profit left for the farmer is so small that it does not pay him to work either himself or his farm to full capacity; so he has adopted the plan of reducing his expenses both of cash and vital energy as low as consistent with a fairly good living for his family, and is simply conserving the resources of himself and his farm until such time as he hopes may come when the farmer will be able to secure a fair share of the profits of his labor.

It would not be a difficult matter to extend the enumeration of the causes which have resulted in decreased farm yields in the Middle West during the last twenty-five years. If, however, I have not already shown that there are many causes other than soil depletion, any further extension of the list would also be equally ineffective. It is not claimed that any or all of the causes are sufficiently general to have actually reduced aggregate crop yields for entire counties or States, but that they are of sufficient frequency to account for the somewhat generally accepted theory that the agricultural resources of this country are becoming rapidly depleted, and they have undoubtedly seriously affected the statistics on the subject.

Another factor that has undoubtedly tended to decrease the average yields, as shown by the statistics of the Middle West, is the fact that much experimenting is being done in attempting to establish agriculture in the semiarid regions where methods have not yet become fully adjusted to climatic conditions, with the result that many very low yields, if not complete failures, are met with.

AGRICULTURAL CONDITIONS IN NORTHERN VIRGINIA.

The agricultural conditions in northern Virginia have not yet recovered from the effects of the civil war, although nearly a half century has elapsed. The former slaves have died or become incapacitated by age, and the younger generation of negroes are very inefficient and unsatisfactory as farm laborers, and their presence tends to discourage the introduction of white laborers on the farms; the result being that labor conditions are even worse here than in the North and Northwest. This portion of the State is producing but a small fraction of what it should. There seems to be an impression that because a large portion of the land is lying idle and yielding no agricultural returns whatever, but is being allowed to grow up to scrub pine and worthless shrubs and weeds, and that because much that is being farmed produces but indifferent crops, that the land is worn out. That such is not the case is, in my judgment, proved by the fact that scattered all over northern Virginia are to be found farms, formerly considered worn out but which have been brought up to a high state of cultivation and are now yielding good returns. The number of these farms is constantly on the increase, and if some solution could be found for the labor problem, it would be quite reasonable to predict that the agricultural production of northern Virginia could be quadrupled within four or five years. It is believed that much the same conditions prevail over a large portion of the entire South.

That the crop yields of all staple products throughout the South are on the increase can not, I think, be questioned, as all available evidence points in that direction. An interesting and significant bit of evidence on this point was secured from an attorney for one of the important southern railroads. I asked his opinion concerning the increase or decrease in crop yields throughout that portion of the South tributary to his road, and he answered immediately and emphatically that there was a marked increase in the yield of all staple farm products, and he went on to state that he had just returned from a meeting of railroad managers where this very point was under discussion, and that after careful consideration of the reports of those who had charge of this question they had come to the conclusion that the yields of all staple crops along the lines of their several roads had been sufficient to warrant them in advancing the freight rates. This was a strong and somewhat unexpected corroboration of the conclusions at which I had already arrived. First, that crop yields are on the increase; and, second, that the transportation companies have better facilities than anyone else for obtaining information concerning any such increase and that as soon as they learn of it they immediately adopt measures to secure to themselves rather than to the farmers any benefits that may come from such increased yields.

UNDEVELOPED RESOURCES, EAST, WEST, AND SOUTH.

Ever since the beginning of American agriculture it has been the custom to refer to "the vast undeveloped agricultural resources of the boundless West." There are still vast undeveloped agricultural resources in the West, but they can no longer be considered "boundless." On the other hand, thousands of eager land seekers and home builders are diligently seeking out every nook and corner of the West that is suited to agriculture, and it is probable that in their eagerness to secure cheap land some of them are attempting to establish homes and farms beyond the bounds of what may safely be considered the agricultural areas.

This tide of pioneers and home builders has been moving steadily westward from the very beginning of American history, and the West has heretofore welcomed them and afforded them with a bountiful hand the opportunities they were seeking. The West will always welcome brain and brawn from the East, and there will always be opportunities there for the right kind of energetic young men and women; but the opportunities to secure cheap land are rapidly decreasing and will at no distant date be little, if any, better than in the East and South. When that time arrives, what is to become of the constantly increasing agricultural population? I predict that it will take the form of a return wave which will bring back to the East and South some of the most energetic and progressive young farmers of the West, who, untrammeled by eastern and southern traditions and customs, will quickly recognize and take advantage of the vast undeveloped agricultural resources of these sections. When that time arrives it will be possible to increase the agricultural production of the country to meet any demands that are likely to be made upon it for many generations to come.

I would therefore sum up my impressions concerning the agricultural resources of the eastern United States, their development and conservation, as follows:

SUMMARY.

1. Crop production per acre is not falling off, but is increasing.

2. The seeming decrease in crop production is generally due to one or the other, or both, of the following causes: (*a*) Changed economic or sociological conditions which have tended to reduce or remove the incentive to maximum production; or (*b*) farmers adopting a more conservative system of farm management which will provide them and their families with a comfortable living with a minimum expenditure of labor—a conservation rather than a dissipation of the potential resources of their farms, with frequently a very marked decrease in the amount of produce sold from the farms, particularly of the more bulky products, such as wheat and corn, which pay a relatively high freight rate in proportion to their value.

3. Agricultural production can best be increased by adopting vigorous measures to remedy faulty economic conditions, and these measures should be directed along the lines of insuring to the farmer a fair share of the price paid by the consumer. This can be accomplished by developing methods of delivering agricultural products as directly as possible from the farm to the consumer in wholesome

and attractive condition, without unnecessary loss or expense in transit and without exorbitant profits to transportation companies and middlemen; and by providing competent and efficient farm laborers at a reasonable wage, including comfortable and attractive country homes.

4. Improved methods of agriculture involve the use of much additional machinery. The manufacture of this machinery is now largely under the control of trusts or combinations which destroy or at least restrict competition and increase the cost to the farmers. Measures should be adopted to prevent such combinations and to insure to farmers an opportunity to purchase all kinds of agricultural implements and machinery at a fair price above the actual cost of manufacture.

5. Liberal appropriations should be provided by Congress and by the several state legislatures for the development of the agricultural investigations now so well under way by the United States Department of Agriculture and by the various state agricultural colleges and experiment stations.

6. No undue effort should be made to stimulate agricultural production until the present faulty economic conditions are corrected, but the campaign for the education of the farmer should be vigorously prosecuted, in order that he may be prepared to meet the demands for increased production when economic conditions have been so corrected that it will be profitable for him to do so.

7. Under proper economic conditions, and with the assistance which will be given him by the United States Department of Agriculture and the state agricultural colleges and experiment stations, if properly supported by liberal appropriations, the farmer will be able to meet any and all demands that are likely to be made upon him for increased agricultural production for many generations to come.

AGRICULTURAL PRODUCTION AS A NATURAL ASSET.

By C. S. Scofield,

Bureau of Plant Industry, U. S. Department of Agriculture.

With comparatively little exception American agriculture is in a condition of transition; that is to say, there are few regions of any considerable extent where any particular kind of agricultural production has been long enough continued to be considered as really permanent. A variety of causes has contributed to maintain this condition, some temporary and others permanent, some economic and some natural, or more truly agricultural. In fact, it would seem that as in the case of our field crops, where a change in the sequence of crops on the same soil has a beneficial effect, so, too, in the type of production for whole regions, a periodic change of some sort has taken place.

As a nation, we have passed through the period when the agricultural production of each region was made as diverse as knowledge and environment would permit, in order to supply local needs, since the transportation of staple products was necessarily expensive. Following there came a rapid extension of agricultural settlement, together with an equally rapid development of means of overland transportation, and this has resulted in a relatively high specialization in crop production, or a localization of crop production to those sections best adapted to the various crops. This tendency toward specialization is now going on at a rapid rate, promoted alike by those agencies which are introducing new crops, and by the zeal of many of our people in seeking crops that will give the quickest and largest returns.

Reactions away from this high degree of specialization are naturally induced by competition in production, by the relatively high cost of transportation, and by the reduced yields which naturally follow the lack of a proper rotation of crops. In looking over any particular section of our agricultural region it becomes apparent that, as regards the kinds of crops and methods of farming, the present condition is essentially temporary. The crops and methods are either newly in vogue or so distinctly unsatisfactory that some change is obviously imperative. Thus the history of our older agricultural sections is a history of the rise and decline of agricultural industries. It is important to keep these facts in mind in making any prognosis of the future of our agricultural productions. As an agricultural people we have not yet "found ourselves."

This being the case, we have as yet no adequate measure for estimating with any degree of accuracy our potential agricultural resources. We hear much of the high productive capacity of the virgin soils of our new regions as compared with that of the worn-out soils of the older regions, but the so-called "exhaustion" of the soils that have been under the plow for one hundred or two hundred years is more apparent than real. It would be difficult, if not impossible, to find any instance of the complete exhaustion of the producing capacity of the soil. It is true that bad methods of farming may render a soil temporarily unfit for profitable production, through the depletion of the supply of organic matter, through ravages of some weed or insect pest, or the ascendency of some plant disease. Any of these difficulties are essentially temporary in character and may be overcome by proper methods of farming.

While it may be true that in time a soil may become unfit for the profitable production of some one crop or group of crops, there is no evidence that any of our once productive soils have as yet become wholly and irredeemably unfit for some kind of profitable agriculture, nor is there any satisfactory evidence of a real irretrievable decline in the productive capacity of any of our truly agricultural regions. Until we have some definite evidence of such a real decline in producing capacity, it will be necessary to accept the conclusion that the productivity of our soils would be maintained indefinitely if a proper sequence of crops and agricultural industries were used.

The relation between the sequence of crops grown on the land and the change in the predominance of industries in a region is necessarily close. Where the sequence of crops is improper, as in the case of the long-continued production of a single crop, or the use in rotation of crops that rapidly reduce the supply of organic matter, the change from one industry to another must come at frequent intervals. If, however, a less destructive system of rotation is followed, so that the producing capacity of the soil for that series of crops is longer maintained, the change from one industry or set of industries to another may be much longer postponed. These facts have been appreciated, more or less unconsciously, by the great body of our farmers. The wisdom of using a rotation of crops and of maintaining the supply of organic matter in the soil is almost universally realized, though, unfortunately, not universally acted upon. When, for one reason or another, one crop or group of crops can no longer be profitably produced in a region, other crops come into use and new industries are established. Owing to this important fact the future outlook is encouraging.

Our greatest national agricultural asset is the character and intelligence of our farmers. If the present high standard of character and intelligence is maintained or improved, the nation need have little fear for the future of its agricultural production. At the present time the mean of our agricultural production is far below the possible maximum, both in gross amount and in yield per area in crop. The present low mean is largely the result of economic conditions. Any material readjustment of these conditions that would require or reward an increase, either in the gross amount of production or in the yield per area, would find an immediate and adequate response. Though the farmers have already done much in using crop rotation, in improving their methods of farming, and in accepting new crops and starting new industries, the end along these lines is not in sight; indeed, only a beginning has been made.

Better rotations are constantly coming into use, better methods of farming are being followed, new and improved crops are constantly finding their places.

The readjustments that take place in our economic conditions must be accompanied by many readjustments in our agricultural production. A higher degree of specialization in crops and methods must be expected in some regions, together with more diversification in others. The facility with which our farmers respond to these economic readjustments, and with which they continue to accept improved methods and more valuable crops, will very largely determine, not only their individual success, but their value to the nation. It becomes, then, a matter of the first importance to insure the maintenance of a high degree of character and intelligence in our farmers. If the future of our agricultural production is threatened, it is through the lowering of the grade of our farmers rather than through the exhaustion of our soil fertility that it is more likely to come.

AGRICULTURAL PRODUCTION.

By W. J. Spillman,
Bureau of Plant Industry, United States Department of Agriculture.

Is crop production per acre falling off? This question must be answered both yes and no. Our study of individual farms leads us to believe that on about 50 per cent of the farms of the country crop production is falling off. The other 50 per cent is about holding its own or increasing slightly. Exceptionally there is a farm on which yield per acre is enormously greater than it was a few years ago. Statistics which have hitherto been gathered on this subject do not reveal the actual status of affairs. These give average yields by States or by counties. They take no account of lands abandoned or put into cultivation, an important factor in many sections. The abandonment of worn-out land and the putting of new land into cultivation may keep up average yields. Nor do statistics reveal the fact that increase in average yields for a given territory is largely due to enormous increases on comparatively few farms, a fact that our investigations reveal to be true. On the whole, the yield per acre of our principal crops has increased slightly for the past two decades, as shown by the following figures:

Average yield per acre for five-year periods.

	Wheat.	Corn.	Oats.	Cotton.
	Bushels.	*Bushels.*	*Bushels.*	*Pounds.*
1891 to 1895	13.4	23.6	29.0	172.3
1896 to 1900	13.2	25.5	23.2	192.4
1901 to 1905	13.9	[a] 27.6	33.0	184.6

[a] Owing to the low yield in 1901, on account of the severe drought, this average is made up for the period from 1902 to 1906.

There is no question that on something like half of the farms of this country the yield is less than when the soil was new. The underlying causes for the condition now existing with reference to crop production are easily apparent to the student of agricultural history and methods.

EXPLOITIVE FARMING.

In a state of nature, soils which are well adapted to the growth of vegetation are maintained in a high condition of fertility. Plant roots thread the soil to great depth. When they decay they not only furnish plant food for succeeding generations of plants, but provide humus, which aids in storing moisture and, perhaps, in removing from the soil deleterious substances thrown off by plant roots. In addition, the continual decay of plant roots leaves channels in the soil which open it so as to permit a free circulation of air and moisture. Animal life in the soil adds to its permeability by making burrows. In some sections of country the common fish worm penetrates soils to great depths, making channels which carry down rain water and thus prevent it from flowing off the surface. For these reasons all soils when first put into cultivation, which are well adapted to the production of plants, are highly fertile. Experience in many States has shown that good virgin soils for approximately half a century after they are put into cultivation will produce good crops with practically no attention to renewing their fertility. Under such conditions the farmer, who naturally follows the line of least resistance, will exploit his soil. He adopts types of farming akin to mining, and continues to draw on the resources of the soil's fertility until it is exhausted, before lessening yields compel him to adopt more expensive methods of farming required for maintaining or building up the soil fertility.

On a new and rich soil very little knowledge is required for the production of profitable crops. All that is necessary is to plow, harrow, plant, till, and harvest, which anyone can learn in a short while. Considerable areas of soil are still found in this country from which the fertility has not been completely mined, so that exploitive farming is still practiced with apparent success in some States. These are the more newly settled regions, the most important of which are the Dakotas, the semiarid plains region, and the upper Columbia Basin of Washington, Oregon, and Idaho. In these the original fertility of the soil still suffices for the production of good crops with the most unscientific methods of farming, though in some of them lessening yields are becoming apparent. In some cases the introduction of weeds which are adapted to growing in grain fields have compelled changes in the system of farming, but the change has in the main been from one exploitive type of farming to another. Very large areas of land in this country have now been farmed about long enough to exhaust their original fertility. This is true of the great body of agricultural lands in the Mississippi Valley extending from the Canadian line to the Gulf, and from the Appalachian Mountains to eastern Kansas and Nebraska. The more progressive farmers in this vast area have adopted systems of farming which tend to build up soil fertility. In some sections the change from exploitive to conservative types has been more or less general, in others it is decidedly sporadic.

There are considerable areas, including the territory east of the Appalachian Mountains and most of the cotton-producing States, in which the land has been farmed much longer than was necessary to exhaust the original fertility. In the northern half of the Atlantic coast region the change from exploitive types of farming has been very general and agriculture is on a fairly sound basis, but in the remainder of this region exploitive farming still remains, and crop yields are much less than they were a generation or two ago. There are several instances of exploitive types of farming that have lingered long beyond their legitimate life. These are found on the average cotton farm of the South, in the tobacco fields of Virginia and Maryland, in the corn and wheat fields of southern Illinois. western Kentucky, and southern Missouri, and in the cornfields of the hill country of the South and of northern Arkansas. The great wheat fields of northern California have just reached the point where waning fertility is evident in the low and generally unprofitable yields. The Willamette Valley of Oregon passed through this stage a dozen years ago, and in that section the change to fruit raising, dairying, and other types of live-stock farming are rapidly bringing the soil back to its original fertility.

COMMERCIAL FERTILIZERS.

The early period of exploitive farming usually gives place to a short period of diversification, during which the more progressive element among the farmers experiments with new types of farming, live stock becoming an important factor. In a short while the best forms of live-stock farming for a given locality are determined and more permanent systems of farming are developed. These maintain or increase the fertility of the soil. But the change from exploitive to conservative types is a difficult one to make. The fact has already been noted that exploitive farming requires only a small degree of intelligence on the part of the farmer. On the other hand, any form of live-stock farming requires more constant attention and a very much greater degree of intelligence. Farmers are prone, therefore, to continue the less strenuous system to which they have been accustomed. In the North, where satisfactory grasses and clovers were early found, and where there are no special difficulties in the way of development of live-stock industries, the adoption of conservative types of farming has progressed in a fairly satisfactory way. In the South, on the contrary, several difficulties have been met with, and the development of conservative types has been greatly retarded.

The difficulty of introducing live-stock farming, especially in the South, and to some extent in other sections, has led to a very general reliance on commercial fertilizers. Twenty years ago the use of these artificial manures was practically confined to the Atlantic seaboard. In the northern part of this section it was confined to the more intensive types of farming, like fruit raising and truck growing, in which the maintenance of soil fertility by feeding stock was out of the question. Farther south fertilizers were very early used in the production of ordinary field crops. The use of commercial fertilizers has extended westward during the past two decades in a remarkable manner. They are now used from the Atlantic coast to eastern Kansas, from the Gulf of Mexico to the Ohio River, and to a considerable extent northward as far as Michigan. According to the census of 1900, the value of commercial fertilizers used in the United States was about $50,000,000. At the present time it is estimated that twice this amount is used. So great has become the dependence on chemicals that in some States fully 10 per cent of the value of the crops is expended in purchasing fertilizers. This is a heavy tax on agriculture, and, while it has served temporarily to maintain yields in most cases, it has greatly decreased the profit from farming. In some sections the continued excessive use of fertilizers has led to injury of the soil from the accumulation of the residue left by the chemicals. Some of the truck soils of the Atlantic coast, on which enormous quantities of fertilizers have been used for many years, have become so charged with these residues that they have been abandoned, and large areas of cotton lands are beginning to show injury from the same cause.

SOIL EROSION.

The northern half of the country has always been more or less covered with various grasses. These have prevented soil erosion except in small isolated areas; but in the South, where a single-crop system with clean culture has been the rule, and where, in consequence, the soils have been left bare during the winter, soil erosion has been an important factor, especially where the land is more or less rolling or hilly. In some sections erosion has proceeded to such an extent that considerable areas have been abandoned.

ECONOMIC CAUSES.

Exploitive types of farming, as already stated, require less knowledge than the more complex types which provide for maintaining soil fertility. Not only that, but they require much less capital. The equipment of an ordinary cotton farm in the South, including buildings, live stock, and implements, does not exceed $10 per acre. On an ordinary grain farm in the West the corresponding equipment amounts to approximately $20 per acre. On a well-equipped hay farm, $40. On the other hand, a properly equipped hog farm must have about $70 per acre expended in buildings, fences, live stock, and machinery in order to put it in condition to return a maximum income. A good dairy farm requires $100 an acre for equipment, and the highest class dairy farms in this country have had $300 per acre thus expended. It is natural, therefore, when we remember that a large part of the West has been settled by pioneers without capital other than their energy and intelligence, that these cheaper types of farming should develop. It is also characteristic for men to live up to their income, hence it is that a change to higher types of agriculture has been retarded by the difficulty of securing sufficient capital. The development of agriculture has, therefore, been retarded both by lack of capital and by the fact that the change from exploitive to conservative types of farming requires knowledge which the average farmer does not possess. In the South special difficulties have existed. In the first place, the prevalence of the cattle tick has made beef production and dairying very precarious. The warm climate has also added greatly to the expense in the handling of milk. Not only that, but the available labor of the South has not been of a type that could easily be taught the management of stock, nor could it be relied on to give that constant attention necessary to success with any class of farm animals. As a result exploitive types of farming have continued in this section long beyond the time when they yield a fair return to labor. This is one reason why the use of commercial fertilizers has extended so much more rapidly in the South than it has in the North.

SHALLOW PLOWING.

In all sections of the country where farming has continued so long that exploitive types of farming are no longer profitable, the decreasing fertility of the soil and the consequent impoverishment of the farmer has led to the use of inferior draft animals, with resulting shallow plowing, so that in many sections only 3 or 4 inches of the top soil is now utilized.

NEED OF INCREASED CROP PRODUCTION.

During the past century the increase in the area of cultivated land in this country has, in general, kept pace with increased demands for farm products, and in some instances has even exceeded these demands. In the case of the wheat crop this is still true. In recent years the lands which have been brought into cultivation have been mainly wheat lands. The average crop of wheat produced during the five-year period from 1895 to 1900 was 540,000,000 bushels. During the next five-year period the average was 660,000,000 bushels, an increase of 22.2 per cent. During the same period the population increased only 9.2 per cent, but during this same period wheat exports decreased over 23 per cent. The increase in the production of corn was slightly less than the corresponding increase in the population. Not only has there been a large increase in area of wheat land in this country in recent years, but there has been a similar increase in other countries, especially in Canada and in Argentina. It is probable that the increase in area of available wheat land will continue for some years to meet increased demands for this cereal, but in the case of corn, the most important crop in this country, conditions are different. For the past few years the increase in the area of corn has not kept pace with the increased demands for this cereal. As a result the price of corn has been higher during the past five years than during any similar period in the history of this country, even with the record-breaking crop of 1906. With the exception of the wheat crop, there is no question that future increases in demand must be met largely by increased yields per acre, and ultimately the same will be true even of wheat. The supply of easily available farm land in this country is well-nigh exhausted. Irrigation projects in the West may add a few million acres and drainage of swamp lands will ultimately add several million acres, but these additions will hardly meet the increased demands for the present and not at all those of the future.

It is fair to assume that the demand for farm products will continue to increase approximately at the present ratio for the immediate future, at least until population begins to press upon the food supply. With practically all of the easily available farm land already in private hands, it is evident that future needs must be met by increased yields per acre. Can this be done? That we shall ultimately reach a condition under which the power of the soil to produce crops can not be made to meet all demands on it seems reasonably certain, but not imminent. When we remember that the average yield of corn in this country is less than 30 bushels per acre, while on the best farms it is more than 100 bushels; that the average yield of wheat is only about 15 bushels, while on many farms it is more than 30 bushels; that the average yield of cotton is two-fifths of a bale, while on many farms it is 1½ or 2 bales, it would appear that with our present area of land it would be possible, by the most approved systems of farming, to feed and clothe twice our present population without requiring too much of the farm. It would probably be possible by united and intelligent effort to double the yield of every important crop in this country. This has been done in the older countries of Europe. In fact Germany, France, and England to-day, on lands farmed many centuries, produce yields practically double those in this country. For instance, the average yield of wheat in bushels per acre in these countries for the period of 1897 to 1906 is as follows: Germany, 28; France, 19.8; and England, 32.2; while the yield for the United States is only 13.8. But to bring about these increased yields exploitive types of farming must be utterly abandoned and in their place types must be developed that provide for maintaining and building up the fertility of the soil. It is no small task to bring about such a revolution in methods of farming.

The point has already been made that conservative farming requires more capital, more expense in operation, and a higher degree of intelligence on the part of the farmer. It also requires better systems of management. How then shall we bring about these better systems of farming which, in the near future, will be necessary to meet the demand for farm produce in this country?

BETTER TYPES OF FARMING.

In the first place, types of farming that maintain or increase soil fertility must be more generally adopted. This means the extension of the various types of live-stock farming and a decrease in the area devoted to crops for sale. It is evident, therefore, that the extension of live-stock farming alone will not meet the conditions. We must, therefore, depend more and more largely upon other means of building up soil fertility. Experience has shown that dependence can not be placed on commercial fertilizers alone. Their indiscriminate use, without attention to the humus content of the soil, has not proved to be satisfactory. Not only that, but the supply of some of the chemicals which have been relied upon in the past to maintain crop yields is not inexhaustible. Practically our whole supply of potash is obtained from a single locality in Germany. The mines which supply this material will undoubtedly be exhausted in the not distant future. The major part of our supply of phosphorus comes from material mined along our South Atlantic coast. As time goes on the supply of phosphorus decreases, and undoubtedly we shall soon reach a period when increased demand and decreased supply will result in a rise in price that will render the use of phosphates less profitable than at the present time. The problem, therefore, is an exceedingly complicated one; even when we exhaust our knowledge of the possibilities in the matter of increasing soil fertility we have not fully met the conditions. This means that scientific investigation on behalf of the farmer, especially as relates to the maintenance of soil fertility, is not yet finished. It is highly important that these investigations should be extended and that encouragement should be given to those who are trying to solve the problems of soil fertility. It is known that much can be accomplished by the growing of cover crops to be turned under for the production of humus. Especially is this true of the legumes, such as cowpeas, soy beans, the vetches, and the clovers. These not only add humus, but because of their power of utilizing atmospheric nitrogen they store in the soil great quantities of nitrogen, the most expensive of all plant foods. The use of such crops, together with a moderate use of commercial fertilizers, greatly enhances the producing power of the soil, and in sections where live-stock farming can not be developed. The farmer must be taught how to use crops of this character. It is seen that the problem is, therefore, largely one of teaching the farmer systems with which he is to a large extent unfamiliar. How shall this be accomplished?

FARM PRACTICE INVESTIGATIONS.

Many of the principles involved in crop production have been worked out through investigations of scientists. On the other hand, practically every intelligent farmer is more or less of an experimenter. There is a vast fund of knowledge in possession of individual farmers of this country, but, generally speaking, the farmer makes no record of his results, and the experience of one farmer is of comparatively little benefit to another. To meet this condition the United States Department of Agriculture has undertaken the investigation of farm practice in all sections of the country. The experience and results of the most successful farmers are collected and correlated, thus adding enormously to our store of knowledge concerning the elements of success in farming. It is fair to assume that half of the growing science of farming, in so far as it has been formulated, is the result of practical experience on the farm; the other half is the result of scientific investigation. While there are many problems yet unsolved, one of the main problems at the present time is how to get knowledge already in our possession into the hands of the farmer. Frequently the problem of the farmer in introducing an important principle into his operations is fully as great as that of the scientist who discovered the principle. There is need, therefore, of a central agency which shall be in intimate touch with the scientist and with those farmers who have worked out important problems, on the one hand, and with the main body of farmers who need information about better systems of farming and better farm methods, on the other. The problem here is that of bringing home to the people the work of the State to aid the farmer. Many agencies are available in this work. The bulletins issued by the States and by the National Department of Agriculture are of much value. The farmers' institutes reach a large number of farmers, and the agricultural press disseminates information; but when all is said and done the fact remains that the average farmer is not in the habit of getting his information from the printed page. He gets it from observation. Not only that, but, as before stated, it is frequently a difficult matter to make use of information, because to do so requires radical changes in the system of farming. An important means, therefore, of getting information into the hands of the average farmer is that of the itinerant teacher. Not only does he become acquainted with the people, thus gaining their confidence, but he learns their problems and he knows the information they need. Direct personal contact is an important factor in influencing the farmer to change his system.

The farmer must be taught how to plan his work with a view to better utilization of farm labor. During the past few years labor has been exceedingly scarce and only those farmers who could give employment the year round have been able to secure sufficient labor to carry on their work properly. Fundamental studies are necessary in order to determine the relation of various types of farming and rotations of crops to the needs of labor at all seasons of the year. These studies are being made by the Office of Farm Management in the Bureau of Plant Industry. The farmer must be taught proper methods of fertilization, improved methods of cultivation; he must be taught the principles of drainage, and in sections where soil erosion is imminent, or is taking place, he must be taught how to prevent it by deep plowing and an abundant supply of humus, and in extreme cases by contour cultivation or by terracing.

IMPROVEMENT OF CROPS.

In addition to better systems of farming and better methods of fertilization, cultivation, etc., much can be done to increase the yield of crops by the introduction of better varieties and by the improvement by breeding and selection of the varieties already at hand. Abundant investigation has shown that an increase of 25 per cent in the yield of our common crops can be produced by the selection of individual plants having high yielding power. There is an especial advantage in this method of increasing crop production in that the use of improved seeds does not require any higher intelligence than the use of ordinary seeds. This is especially true of new varieties of fixed type which are of superior merit, for when the farmer once secures a small amount of the seed of such a crop he obtains a permanent increase in yield, even where his methods are not changed at all.

ACCIDENTAL LOSSES.

The yield of nearly all crops in this country is decreased to a considerable extent by the ravages of insects and by fungous diseases. These are in many cases preventable. The methods required, however, call for considerable intelligence, and constant effort is necessary to get the farmer to use them. It is a legitimate function of the State to teach the farmer the use of remedies for these pests.

It will not suffice to maintain agricultural production merely to teach one generation of farmers how to farm. The personnel of the farming community is continually changing. New men embark in the business and young men grow up to assume the duties of their elders. These new farmers must in the main be taught over again the lesson learned by those who preceded them. The task of teaching the farmer will, therefore, never be finished. It is abundantly demonstrated, however, that when the task is properly done, the soil at present available in this country may feed and clothe a population enormously greater than that which it now does.

INTERPRETATION OF CROP STATISTICS.

By Dr. A. C. True,
Director of Office of Experiment Stations, U. S. Department of Agriculture.

Although the data show an increase in the average yield of different crops for the ten years, 1897–1906, as compared with the average for the forty years, 1867–1906, they do not necessarily indicate an actual increase in the amounts of plant food in the soil, taking the country as a whole, nor do the average low yields for certain periods definitely mean a decrease in the quantity of plant food at those times. It is to be expected, however, that in certain sections this natural resource has diminished through improper management, but the depression is entirely obliterated in the average figures by conditions and circumstances incident to the development of new regions and not infrequently by accidental climatic conditions and other forces.

In the interpretation of the crop statistics for the last four decades a number of factors must be considered. Some of these are general, while others are local and incidental. The influence of our agricultural experiment stations is limited to the twenty years since they became generally established. In most States agricultural colleges have not been well established longer than the experiment stations, while farmers' institutes and other agricultural extension work are of a still more recent date. The agricultural short courses and winter courses, which are now attended by thousands of farmers and farmers' sons, are the development of comparatively recent years. In fact, many of the factors just mentioned can have had an effect on crop production only during the last ten or fifteen years. The principal forces with a bearing on crop yields are the works of the United States Department of Agriculture, agricultural experiment stations, agricultural colleges, farmers' institutes, and state boards of agriculture, the agricultural press, the better adaptation of crops to the conditions of soil and climate by seedsmen and plant breeders, the more liberal and more rational use of fertilizers, better methods of farm management, especially in the diversification and rotation of crops or the introduction and substitution of kinds and varieties of crops in particular sections, the progress in the improvement of agricultural implements, and the increase in the value of the crops and of the land.

All these influences are now widely operative in the United States and undoubtedly are doing much toward the general improvement of our agriculture and the maintenance of soil fertility.

Other factors of wide influence, however, affect the average crop yields of limited periods, and these must be taken into account in the analysis of crop statistics. This is decidedly the case in the periods now under consideration. For example, in considering the average yields for the different decades account must be taken of the fact that during the period of 1897–1906 the number of good crop years was greater than in the preceding decade. Statistics of this department show that from 1887–1896 the average yield of corn was low in 1887, 1890, and 1894; of wheat in 1888, 1890, and 1893; of oats in 1890 and 1893; of barley in 1887 and 1894; of rye in 1887, 1888, 1890, and 1892; of buckwheat in 1887 and 1888; of potatoes in 1887, 1890, 1892, and 1894; and of hay in 1887, 1890, 1891, 1892, 1894, and 1895; while from 1897–1906 they indicate a low average yield of corn only in 1901, of barley in 1900, and of potatoes in 1897 and 1901. This fact contributes as much, if not more than any other, to the reduction of the average yield for the decade of 1887–1896 and the very perceptible increase for the decade 1897–1906. An almost unusual succession of good crop years in the last decade has had its effect in bringing the average for this period above the average for forty years. Undoubtedly some of the larger average yields in the first decade here considered are due to the fertility of new lands, while some of the reduced average yields of later periods may be due to a decline in fertility in some of the older farming regions. The universal custom in new regions has been the continuous taking of crops from the soils without putting anything back in the way of manure, etc.

A strong incentive to farm with greater care and thoroughness is the increase in the value of farm lands and farm products and the consequent increase in land rents. On the one hand, greater returns are required to maintain the rate of income on the present valuation, and, on the other, the enhanced value of the products, together with the rapid decrease of new lands suitable for agriculture, makes it incumbent upon the farmer to use more care and skill in his work.

By considering each crop separately the effect of some of the principal influences tending to raise or to lower the average yield may be brought out more clearly. The increase in the average corn yield per acre in the northeastern part of the country, from Maryland to Maine, has been due, among other things, to the extension of the dairy industry in that section. In dairying, the grain and roughage produced on the farm are fed to the cows and the comparatively large quantities of manure produced are returned to the soil, with the result that the fertility and consequently the average yield is brought up. Furthermore, in the New England States farmers in certain sections are beginning to grow the higher yielding Dent varieties of corn in place of the Flint varieties. Throughout the corn belt seasons have been quite favorable in recent years. The methods of cultivation, largely due to experiment-station work, have been improved, and as a result of station and extension work a much more rational selection of seed corn is practiced. This is noticeably true in Indiana, Illinois, and Iowa, where the average yield has considerably increased during the last decade. The high average yields of earlier periods are probably due largely to the initial fertility of the soil. It is also a fact that as some of the States were settled the best lands were first brought under cultivation, and therefore the average yields are highest in the earliest decade. Kansas and Nebraska and all of the States of the plains were first settled along the river valleys in their eastern parts, where both soil and climatic conditions were most favorable, and for this reason the average yield of crops for this period shows up well, while later on, when settlers worked westward and were obliged to take greater risks, especially with reference to precipitation, the average yields naturally decreased. This condition makes it extremely difficult to definitely interpret crop statistics for the States which were settled during this period. In this case the lower average yields of later decades do not indicate a reduction of fertility. The statistics for corn bring out this fact better than those for wheat, because corn was not so subject to the attacks of the chinch bug in some of the earlier periods.

Wheat production has been very favorably influenced by the introduction of varieties better adapted to certain regions. The durum wheats, introduced by this department since 1900, have proven to be drought and rust resistant, outyielding most spring varieties in dry seasons. About 50,000,000 bushels were grown in 1907, which represents more than one-twelfth of the entire wheat production of the country for that year. In addition the winter wheat area, through the introduction of hardier types, has been extended farther north, this being particularly true in Nebraska, and to a lesser extent in Iowa. In this section winter wheat usually yields better than spring wheat, while the average yield of spring and winter wheat for the whole country shows but little difference. In nearly all those States in which dry farming and irrigation are practiced, the average yield of wheat has gone up, mainly because these methods of farming are becoming better understood, or, in other words, the farmer has become more efficient in the utilization of the plant-food resources present in the soil. In some of the older and principal wheat-producing States where up-to-date methods are in use and where wheat improvement has been carried on by experiment stations and other agencies, the average yield has declined, but this may be taken as showing that on the one hand the soil fertility has gone down, while on the other the opposing factors have not been quite efficient enough to overcome the decline in yield due to this cause.

The same statements in general may be made in regard to oats and barley, and attention may be called to the figures given for Montana, Idaho, Utah, and Washington. These remarkable increases in the average yield do not mean that more available plant food has been added to the soil, but that more finds its way into crops because of improved and more efficient methods. In Wisconsin, Manshury barley, introduced and disseminated by the experiment station, has become the standard barley of the State, and has proved a very practical barley for the Northwest. This is evidently one of the principal factors which has brought up the average yield, almost 4 bushels per acre during the last decade.

The data on potatoes hardly admit of general conclusions. This crop is frequently neglected when other lines of work are more profitable, and especially when the farmer aims to grow enough for his own use only. In some of the Eastern States, for instance, where the dairy industry has recently made such rapid strides, the potato crop, and especially commercial potato growing, has fallen out of favor to some extent and a loss of average yield has been sustained. The high average yield in Maine for 1897–1906 is principally due to the development of the Aroostook County potato-growing region of virgin soil. The Maine Experiment Station has been of very material assistance in bringing into use more rational methods of applying fertilizers and establishing the practice of spraying against potato diseases.

In summarizing, it may be said that the data presented in the tables show how the average yields for any given period may vary as compared with those of another period and that the crop-producing power of our soils, taking the country as a whole, during the last forty years has not decreased. The explanations given above are not complete, as they suggest only briefly in what ways different factors may be active. The campaign of agricultural education, continuously carried on by this department, the agricultural experiment stations, agricultural colleges, and other means of agricultural instruction, has for its object the improvement of agricultural conditions in general, and this is largely brought about by increasing or at least maintaining the crop-producing power of the land. In reviewing results, however, it is impossible to say exactly how much credit is to be given to each factor, as data are not to be found from which such conclusions might safely be drawn. Further, the variation of the average yields between different periods can not be interpreted as meaning a corresponding decrease or increase in the amount of available plant food present in the soil.

During the past decade the American farmer has been stimulated and encouraged by generally favorable weather and rising prices for farm products. At the same time he has had the aid of a system of agricultural education and research, organized under national and state auspices, which for the first time in the history of this country has become widely diffused and broadly efficient. Agriculture under these conditions has rapidly improved and become a hopeful and progressive industry. The problem now is to diffuse agricultural education so thoroughly and effectively that the great mass of our farmers will be able, even under more adverse conditions, to more than hold their own in the world's competition and maintain unimpaired the fertility of our soil for the benefit of succeeding generations.

THE CONSERVATION OF THE FERTILITY OF THE SOIL.

By Dr. H. W. Wiley,
Chief of Bureau of Chemistry, U. S. Department of Agriculture.

In compliance with the request of the President of the United States, I offer to the commission appointed for the conservation of our natural resources the following observations upon the conservation and increase of the fertility of the soil.

This is a problem which has from the earliest times been of interest to all persons connected with agriculture. In 1788 the Philadelphia Society for Protecting Agriculture, recognizing the importance of this problem, took steps to secure a proper discussion of it. This society offered premiums for the discussion of certain problems relating to agriculture, among which I may mention the following:

III. For the best method of counteracting the injurious effects of frost, in heaving or spewing up ground and exposing roots of wheat to the drying winds of the spring, founded in experience, a gold medal, and for the second best a silver medal. The account to be presented to the society by the 20th of December next.

V. For the best method of recovering worn-out fields to a more hearty state, within the power of common farmers, without dear or far-fetched manures; but, by judicious culture, and the application of materials common to the generality of farmers, founded in experience, a gold medal; and for the second best a silver medal. To be produced by the 20th of December, 1788.

VI. For the best experiment, soil and other circumstances considered, in trench plowing, not less than 10 inches deep, and account of the effects thereof, already made or to be made, on not less than one acre, a gold medal; and for the second best a silver medal. To be produced by the 20th of December, 1789.

VII. For the greatest quantity and variety of good manure, collected in one year, and best managed, from materials common to most farms, regard to be had to the proportion and goodness of such manure, and the quantity and goodness of the arable and grass lands of the whole farm on which it is obtained, a gold medal; and for the second best a silver medal. To be claimed by the 20th of December, 1789.

XI. For the greatest quantity of ground, well fenced, in locust trees, or poles of the sort used for posts and trunnels, growing in 1789, from seed sown after this time, not less than one acre, nor fewer than 1,500 per acre, a gold medal; for the second best, a silver medal. To be claimed in December, 1789.

XIV. For the best method, within the power of common farmers, of recovering old gullied fields to a hearty state, and such uniformity or evenness of surface as will again render them fit for tillage; or, where the gullies are so deep and numerous as to render such recovery impracticable, for the best method of improving them, by planting trees or otherwise, so as to yield the improver a reasonable profit for his expenses therein, founded on experiment, a gold medal; and for the next best a silver medal. To be produced by the 1st of January, 1790.

From the above list of problems submitted for discussion it will be seen that the importance of the conservation and increase of the fertility of the soil was thoroughly recognized at that epoch. The prospectus stating the problems to be discussed was issued by the society over the signature of its secretary, Samuel P. Griffitts, on the 5th of February, 1788. The prospectus was published in the Columbian Magazine for February, 1788. I have not yet been able to find any printed copies of the answers to these problems, although I am still on the lookout for them. It would be of the greatest interest at the present time if the views which were entertained immediately subsequent to the Revolutionary war on this important subject could be considered, and later on I have given a summary of them. In the further consideration of this subject I will first call attention to the problem of washed soils.

In 1894 I embodied in Farmers' Bulletin No. 20, in collaboration with the divisions of Soils, Forestry, and Botany, my ideas of the best methods of recovering washed soils. The part which I contributed en bloc is found on pages 7–11, which is as follows:

Along the banks of the Ohio River and in very many portions of the South hundreds of fields that were once covered with sturdy forests of oak, maple, walnut, and pine, and which bore under cultivation, after being cleared of the natural growth, large crops of wheat, maize, tobacco, and cotton, may now be seen furrowed with gullies as with the wrinkles of age, and abandoned to brush and briers.

A surface layer of good agricultural soil 6 inches deep resulting from the slow and gradual disintegration and decay of rocks and accumulation of humus may have required hundreds of years for its natural formation, and yet it is liable to be washed away in a single storm.

This excessive erosion, or washing, of lands may be prevented, and the already gullied fields may be recovered, and steep slopes of loose material may be held and prevented from washing—

(1) *By chemical means*, in the application of manures and fertilizers and in the accumulation of organic matter, which change the texture of the soil and make it more porous and more absorbent of water, so that there is less to run off over the surface.

(2) *By means of cultivation and underdrainage*, which prevent erosion by distributing the surface flow over the ground and increase the amount carried off by underdrainage.

(3) *By reforestation*, or the planting of trees, which act mechanically to prevent washing.

(4) *By grass and similar vegetation*, which bind the soil grains and prevent their washing away.

The erosion of a soil is caused by the wearing of the rain and snow waters which can not penetrate into the soil fast enough to be carried away by underdrainage, and which, by reason of the slope or contour of the land, run off over the surface, carrying along particles of sand and clay. When this water accumulates in a depression in the field the force of the torrent may be sufficient to cut out a great gully in a short space of time.

The extent of washing to which the soil is exposed depends upon the quantity of rainfall in a given time, the slope or contour of the surface, the texture of the soil, the vegetative covering of the surface, and the kind and condition of cultivation. A soil composed chiefly of moderately coarse grains of sand, and having good underdrainage, will absorb the heaviest rainfall without much danger of surface erosion. A clay soil, on the other hand, into which the water can not percolate with anything like the rapidity of the precipitation will be washed and gullied by the torrent of water which must flow over the surface.

CHEMICAL RELATIONS OF THE SOIL TO SURFACE WASHING.

It has been repeatedly shown by experiments and by the experiences of farmers that a soil, as a rule, absorbs water more readily as the content of organic matter and of humus increases. Surface erosion can, therefore, be largely prevented by such a system of cultivation and cropping as will introduce as large a quantity of organic matter into the soil as possible. A very old method of recovering washed and gullied land is to place straw in the furrows while plowing, the straw not only acting mechanically to hold the soil in place and prevent surface erosion, but also in a very efficient way to increase the quantity of humus, thus making the soil hold large quantities of water which otherwise would have passed off over the surface. In this simple way fields which have been badly washed and gullied and entirely abandoned may be recovered and made highly productive.

The most important thing in the recovery of waste fields is the incorporation of organic matter of some kind in the soil; pea vines, stubble, briers, or leaves from the forest may be used as a source of the organic matter. The straw from one acre of land which has been recovered, as mentioned above, will be sufficient to start the recovery of another acre, even if this be deeply furrowed with gullies. Where enough organic matter can be used as a surface dressing, this layer helps greatly to retain water and to make the underlying soil more absorbent.

As soon as a sufficient supply of humus has been accumulated and the lands are brought up to an adequate condition of fertility, clover or grass should be seeded, if the land is at all suited to these crops, or rye, oats, or field peas should be sown to help hold the surface. Little by little, but more rapidly than would be expected from the forbidding aspect of the field, the land can be reclaimed again and made productive through the accumulation of humus and organic matter. A soil containing a fair quantity of humus will wash less readily than one nearly destitute of this matter.

A soil containing a fair supply of lime is much less liable to wash than one similarly situated and exposed which is deficient in lime. The reason of this is that clays which are deficient in lime, when once brought into suspension by moving waters, will remain in suspension and keep the water turbid for a long time. Clays which are heavily impregnated with lime salts, on the other hand, are in a flocculated state, the fine grains of clay being held together and in contact with the larger grains of sand. This flocculated mass quickly settles and is originally not so easily disturbed and carried off by moving water. A field treated with an abundance of lime is thus less easily washed by heavy rains. The results of investigations by Schulze, Schloesing, and Hilgard have shown in a most emphatic way the beneficial changes which take place, especially in stiff clay soils, by the application of lime.

The change in the physical condition of the soil which is produced by the lime, and which is likewise produced by a number of other chemicals ordinarily used in commercial fertilizers, is another important factor worthy of consideration. A stiff clay soil is practically impervious to the penetration of surface water when it is delivered in such torrents as we are liable to have in our summer storms. A well-limed soil, on the contrary, although it may contain as much clay but in which the particles are flocculated or drawn together, is much more pervious to water, and the amount of water which the soil will carry down through underdrainage is increased, and the excess which has to flow off over the surface is diminished. The surface washing of cultivated fields, especially those which are naturally deficient in lime, can be greatly diminished, therefore, by the free application of this substance to them.

A number of the ordinary fertilizing materials have an important effect upon the texture of soils and upon the permeability of soils to water, but few systematic investigations have been carried on in this line and not much, except of local importance, has been definitely settled by experiments or by the experiences of farmers.

From the above it is seen that the problem of washing may be partly controlled at least by the chemical treatment of the soil in such a manner as to render the particles more adherent and tenacious and less liable to disintegration under the action of rain. The tendency to wash may also be largely overcome, except in case of excessive rainfall, by deeper tillage. If the hard underlayer of the soil on the hillside could be broken and softened to the depth of from 12 to 18 inches the quantity of water which would be retained by the soil before starting to run would be greatly increased and thus the amount of washing would be to that extent diminished. Only those who have lived in localities in which the soils are subject to washing, as I have, can realize the great importance of making efforts to counteract it. The methods of holding the soil by grass and by various trees are, of course, the most effective, but these take the soil away from tillage and thus, to a certain extent, restrict the farmer's activities in the growth of ordinary field crops. The contour method of tillage is also a great aid in this respect, and it should always be resorted to in connection with chemical and mechanical means of avoiding erosion. By careful attention to details of this kind it is easy to see that large areas may be restored to tillage which have been virtually abandoned and allowed to grow up in brush and briars.

In an address delivered before the American Association for the Advancement of Science, Section C, in 1886, I discussed the economical aspects of agricultural chemistry. This discussion was largely in the line of the conservation of plant food, which was made the subject of another discussion at a later period, as I shall mention further on. Without attempting to recapitulate here the statistical data on which the argument is based, I will call attention to some of the principal conclusions reached in this discussion. It was shown that the total value of plant food—that is, potash, phosphoric acid, and nitrogen—removed from the soil in the agricultural crops of the United States at that period had a market value of three and one-third billion dollars. Of course the market value at the present time has increased not only in proportion to the crops but also in actual cash value for the ingredients mentioned. In commenting upon this point I said:

> These quantities of plant food removed from the soil annually seem enormous, but it must be remembered that they are not all lost; much of them is left in the soil, in roots, straw, stalks, etc. Those, however, who are acquainted with the method of farming practiced in the newer parts of our country know that cornstalks and straw are generally regarded as nuisances, to be removed as easily and speedily as possible. It is not tilling the soil, but killing it, that is practiced. Stables are removed to get out of the way of the accumulating manure, and the cornstalks are raked together and burned to prepare the field for a new crop. True, in many localities the waste of such a proceeding, especially in nitrogen, is understood. Yet it must be confessed that over vast areas of our agricultural lands there is no conception of the idea of possible exhaustion of the soil, and no systematic method of preventing it. The refuse of the crop, the straw, the stalks, etc., are put out of the way as easily and quickly as possible, and without thinking of the robbery which is thereby committed.
>
> The stores of plant food which have accumulated in our virgin soils are indeed great, but they can not withstand this constant drain on them. The effects of this system of culture soon show themselves in diminished yield, as is seen in the great wheat fields of the Northwest and of California, which do not produce at the present time more than half the crop at first obtained from them.

It is interesting to note that at that time, in 1886, long before the discovery of the rôle of leguminous plants in producing nitrification, the importance of this process was fully realized in agriculture. I say on page 21:

> It would not be proper to take time here to enter into a detailed discussion of the process by which organic nitrogen, or nitrogen of any kind, is converted into nitric compounds, a process which is of the utmost importance to vegetable growth and which it is now generally conceded is due to a kind of fermentation set up by a special organism. Thanks to the results of the patient and fruitful investigations of Pasteur, it has been possible to secure pure cultivations of this nitric ferment. Perhaps the chief credit of this achievement is due to Schlosing and Muntz,[a] but the part taken in it by Warrington, Berthelot, Deherain, and Joulie must not be forgotten.

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[a] Comptes rendus, Vol. LXXXIV, pp. 301 et seq., and Vol. LXXXIX, pp. 891 et seq. and 1074 et seq.

The dangers which were to be apprehended from denitrification were also fully set forth at that time, as will be seen by the following quotation:

A process directly the reverse of nitrification has also been observed by Gayon and Dupetit,[a] by which nitrates are destroyed by a denitrifying ferment. This ferment is described as an anaerobe. It acts most vigorously at a temperature of from 35 degrees to 40 degrees, and the experimenters, under favorable conditions, succeeded in totally decomposing a 5 per cent solution of nitrate of potassium. Heat, chloroform, or sulphate of copper sterilized the solutions; but carbolic and salicylic acids do not interfere with the fermentation, on the contrary, are themselves decomposed, like organic matters. The gas evolved is pure nitrogen, representing a large portion of the nitrogen originally present in the nitrate. The rest of it forms ammoniacal compounds.[b]

Again, on page 32, I say:

In the light of the investigations of the last few years it may be well to admit that the opinion held by the vast majority of agronomists and agricultural chemists and physiologists, that the free nitrogen of the atmosphere never is assimilated by the growing plant, should be held open for revision.

The general belief among scientific men who have paid attention to this matter has inclined to the opinion of Lawes and Gilbert, Pugh, and Boussingault that the growing plant does not in any circumstances assimilate the free nitrogen of the air. So widespread was this opinion that before the investigations just noticed, when Atwater[c] published a series of experiments showing the contrary, it was thought some factor in the investigation had been overlooked. According to Atwater's results it appears that "the plants grown in nutritive solutions exposed to the air, but protected from rain and dew, contained at maturity much more nitrogen than was supplied them in nutritive solution and seed."

This is certainly a definite and unequivocal statement, and it was followed by "for this excess of nitrogen there was but one possible source, namely, the atmosphere."

All these elements in the conservation of the plant foods in the soil naturally must be construed in connection with the food supply of man himself, and this led to the following observation in the paper read in 1886, as follows:

Since with a proper economy the natural supplies of potash and phosphoric acid, as we have seen, may be made to do duty over and over again and last indefinitely, the economist who looks to the welfare of the future need have no fear of the failure of these resources of the growing plant. Indeed, it may be said that the available quantities of them may be increased by a wise practice of agriculture based on the teachings of agricultural chemistry.

But with the increase of population comes an increased demand for food, and therefore the stores of available nitrogen must be enlarged to supply the demands of the increased agricultural product. It is certain that, with the new analytical methods and the new questions raised by the investigations of which I have spoken, many series of experiments will be undertaken, the outcome of which will definitely settle the question of the entrance of free nitrogen into vegetable tissues. If this question be answered affirmatively, agricultural science will not place bounds to the possible production of foods. If the nitrifying process does go on within the cells of plants, and if living organisms do fix free nitrogen in the soil in a form in which at least a portion of it may be nitrified, we may expect to see the quantities of combined nitrogen increase pari passu with the needs of plant life.

Thus even intensive culture may leave the gardens and spread over the fields, and the quantities of food suitable for the sustenance of the human

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[a] Comptes rendus, Vol. XCV, pp. 644 et seq.

[b] Gayon and Dupetit report the latest results of their investigations of the denitrifying ferment in the Journal de Pharmacie et de Chimié, July, 1886, pp. 34, 35.

[c] Am. Chem. Jour., Vol. VI, pp. 365 et seq.

race be enormously increased. In regarding the agricultural economies of the future, however, it must not be forgotten that a certain degree of warmth is as necessary to plant development as potash, phosphoric acid, and nitrogen.

If it be true, therefore, that the earth is gradually cooling there may come a time when a cosmic athermacy may cause the famine which scientific agriculture will have preveuted.

Fortunately, however, for the human race, the cereals, the best single article of food, are peculiarly suitable to a cold climate. Barley is cultivated in Iceland, and oatmeal feeds the best brain and muscle of the world in the high latitudes of Europe.

It is probably true that all life, vegetable and animal, had its origin in the boreal circumpolar regions. Life has already been pushed half-way to the equator, and slowly but surely the armies of ice advance their lines. The march of the human race equatorwards is a forced march, even if it be no more than a millimeter in a millennium.

Some time in the remote future the last man will reach the equator. There, with the mockiug disk of the sun in the zenith, denying him warmth, flat-headed and pinched as to every feature, he will gulp his last mite of albuminoids in his oatmeal, and close his struggle with an indurate inhospitality.

The waste and conservation of plant food was studied in a systematic manner as applied to soil fertility in my address as retiring president of the American Chemical Society at the Baltimore meeting of the Society on December 27, 1893. The problem which was presented at that time was stated in the following language:

One of the greatest of the practical problems presented for solution by agricultural chemistry is the conservation of plant food. With an abundance of plant food and a favoring climate, it is difficult to place a limit to the power of the earth for supporting life. We have read much in political economy of the limit of subsistence, and one bold philosopher has based a theory of the limitation of the number of human beings upon the earth on the insufficiency of the earth to support a greater number. Happily, however, the Malthusian philosophy was promulgated before the days of that great agricultural renaissance which has been brought about chiefly through the efforts of experimental agricultural chemistry. I am not so blinded by the achievements of agricultural chemistry as to deny to many other branches of science au important and, in many cases, necessary influence in this development of agricultural science; but I think every candid man will admit that in this development chemistry has always taken the front rank and led the way. This is preeminently true of the investigations into the nature and extent of the plant food available on the surface of the earth. In this country, owing to the great stores of wealth which the past had accumulated in the soil, it is only within recent years that the question of the supply of plant food has assumed any practical importance. As long as there were virgin fields at the disposal of the agricultural rapist, the conservation and restoration of exhausted fields were of little consequence. The result has been that the wealth of hundreds or, perhaps, thousands of years slowly stored in the soil has been poured forth in a century, not only for the enrichment of this country, but for the benefit of all countries. Unfortunately or fortunately these stores are now practically explored and there is little left in this land of virgin fertility to tempt the farmer to new couquests. Not only have these stores of plant food been utilized but, much to the discredit of the American farmer, they have been wasted. The mark of good agriculture is to see fields yielding annually good returns and increasing or at least not lessening in fertility. This beiug true, the history of American agriculture to within a few years must be the history of bad farming, for everywhere we have seen fertile fields losing their fertility and farms once productive abandoned. No difference how great the store may be, if it be continually drawn upon and never replenished, the day will some time come when it will be exhausted. This day has come to a large portion of the agricultural lands of this country and to-day there is an awakening everywhere in regard to the best methods of checking the waste and of restoring what has been lost.

I desire for a brief period on this occasion to call the atteution of the chemists of this country to some of the methods by which plant food is removed from the fields aud some of the direct and indirect ways in which it is and may be returned. On a former occasion[a] I have discussed the extent to which plant food is removed from the soil directly in the crops and the dangers which arise to an agricultural community which continually exports its agricultural products. On that occasion I pointed out the amount of potash, phosphoric acid, and nitrogen per acre annually removed by the crops of the United States, and showed that the only safe agricultural products to send out of a country were sugar, oil, and cotton. It is true that with native, unexhausted soils a country may acquire great wealth by agricultural exports, but the history of the world shows that a country which depends for its wealth and its commerce on agricultural exportation is in the end reduced to pauperism. A single example may serve to accentuate this remark; I refer to the island of Cyprus, which two thousand years ago was the granary of many cities bordering on the Mediterranean Sea. Supplying hundreds of thousands of people with corn, it gradually became impoverished, and to-day its soils are perhaps the poorest of any known.

The waste to which I desire to call your attention to-day is not that which normally takes place in the production of a crop, but that which is incidental to the cultivation of the soil and to a certain extent unavoidable. My purpose is to develop, if it be possible, the relations of agricultural chemistry to this waste, with the purpose of pointing out a course by which it can be returned and in what way we may at least reduce to a minimum the unavoidable removal of valuable plant food. You have all, perhaps, surmised the character of this waste; I refer to the denudation of fields by water and to the removal of soluble plant food by the percolation of water through the soil.

The losses due to the denudation of fields are purely of a mechanical character. The natural forest, or the natural covering of grass over an area of soil, prevents, to a large extent, the denudation due to heavy downpours of rain. The removal of the forest and the destruction of the grass by cultivation leave the soil in a condition in which it is unable to resist the action of flowing surface water. The muddy character of the water in all streams bordering on cultivated hilly fields after a heavy rain storm is a familiar instance of the tremendous energies which are exerted by a heavy downpour of rain in the carrying of the soil into the streams and its transportation toward the sea.

It is not necessary to emphasize the fact that the agricultural chemist is practically powerless to prevent the surface erosion due to heavy rains, but a few practical lessons derived from the application of chemical discoveries to the soils show how, in a certain measure, even surface erosion may be controlled, or at least reduced to a minimum, by the application of the principles of culture founded upon the facts disclosed by advanced science.

The observing agriculturist will have noticed that even in a hilly country a soil in situ underlain by limestone is less likely to be cut up by gullies than a soil similarly situated and deficient in carbonate of lime. The reason of this is plain. In a soil deficient in lime the clays when once brought into suspension by moving water assume a semicolloid state and remain indefinitely in suspension. Clays, on the other hand, which are heavily impregnated with lime salts are in a flocculated state, and the larger aggregates thus produced settle quickly. The result of this is that such a soil is less easily moved by water and a field thus treated less exposed to washing by heavy rains.

The change in the physical condition of the soil which is produced by the lime is also another important factor worthy of consideration. A stiff clay soil is almost impervious to the penetration of surface water, and thus the amount which is carried off is raised to a maximum. A well-limed soil, on the contrary, in which the particles are perfectly flocculated, is much more pervious, and the amount of water which will be retained and delivered gradually to vegetable growth is much greater. Thus the beneficial effects of lime are manifested in both ways—in the better retention of the flocculated clays and in increasing the capacity of the soil for holding a given amount of water in its interstitial spaces.

There are many other salts which also have the same properties as those of lime, but I have spoken of lime salts chiefly because they are cheaper and therefore more economically applied. Perhaps, next to lime, common salt would be the most efficient in producing the results already described; but common salt, being extremely soluble, would soon be leached out of a soil. On the other hand, lime, even when supplied as hydrate, in which case it is somewhat soluble,

[a] Vice-presidential address before the American Association for the Advancement of Science, Buffalo, 1886.

quickly becomes converted into a carbonate which is practically insoluble in water which does not contain an excess of carbon dioxide.

I am aware of the fact that liming to prevent erosion by surface drainage has not been emphasized as an example of the benefit of the proper chemical treatment of soils, yet I feel sure that all who will give the subject a thoughtful consideration will agree with me in saying that this aspect of the subject is one of no small importance, especially when considered in respect of hill fields, and even of fields of more level surface.

Without dwelling long upon this point, it is only necessary to call your attention to the immense quantities of soil material annually conveyed to the sea by the causes of erosion already mentioned to show what an active and powerful foe the farmer has in this source of loss. Any one who watches, even for a short time, the volume of water carried by the Mississippi into the Gulf of Mexico will have a most effective object lesson in regard to this source of loss.

A more striking lesson may be seen in the hill regions bordering both banks of the Ohio River. Hundreds of fields once covered with sturdy forests of oak, maple, and walnut, and afterwards bearing large crops of maize, tobacco, and wheat, may now be seen furrowed with gullies, as with the wrinkles of age, and abandoned to brush and briers. The same is doubtless true of other hill regions, but I speak the more advisedly of those which have come under my personal observation.

Great, however, as the mechanical loss of plant food is, it is by no means as dangerous as the loss of the soluble materials caused by the percolation of the water through the soil. The study of the nature of the loss of these soluble materials, together with the estimation of their amount, forms the subject of lysimetry. Agricultural chemists have used many devices for the purpose of determining the character and amount of the natural drainage of soils. Evidently the treatment of a specially prepared portion of soil by any solvent, although giving interesting results, does not indicate the natural course of solution. The only way in which this can be determined is to be able to collect, measure, and study the character of the drainage from a given portion of the arable surface of the earth in situ and under normal conditions. Various methods of lysimetric investigation have been proposed and used, all of them possessing many points of value.

This paper discussed not only the sources of loss of plant foods, but also the methods by which the lost plant food may be recovered and restored. Special chapters are given to the conservation of nitrogen and the increase in its quantity; to the potash deposits and the likelihood of discovering additional deposits to those which are found in Germany; also to the question of phosphoric acid and its increased supply. The progress of the soluble plant foods from the time they are leached from the soil until they are carried into the ocean is traced, and also the methods by which they may be restored to the use of man. The conclusions derived from this study are as follows:

From the foregoing summary of the methods of waste of plant food it has been seen that in spite of all the precautions of the farmer and the chemist, and in spite of the selective absorption of the soil, immense quantities of valuable plant food are carried into the sea, where apparently they are lost to agriculture forever. But this is only an apparent loss. The economies of nature are so happily adjusted as to provide a means of gradually returning in some form or other to the power of the farmer the plant food which has been apparently destroyed. It is true that this return will probably not be to the locality where the waste originally occurred, and it may not take place until after the lapse of thousands of years, but this is of no consequence. Provided arable lands in general receive in some way and at some time a certain return for the plant food removed, it is entirely immaterial whether this be the original plant food removed or other equally as good.

The sea is the great sorting ground into which all this waste material is poured. The roller processes of nature, like the mills of the gods, grind exceedingly slow and small, and the sea becomes the bolting cloth by which the products of milling are separated and sorted out. As soon as this waste material is poured into the sea, the process of sorting at once begins. The carbonate of lime becomes deposited in vast layers, or by organic life is transformed into immense coral formations or into shells. Phosphoric acid is likewise sifted out into phosphatic deposits or passes into the organic life of the sea. Even the potash, soluble as it is, becomes collected into mineral aggregates or passes into animal or vegetable growth. All these valuable materials are thus conserved and put into a shape in which they may be returned sooner or later to the use of man. In the great cosmic economy there is no such thing as escape from usefulness of any valuable material.

In these papers I did not take up the possibilities of increasing the food supply of plants by the action of leguminous crops, nor by the modern method of producing nitric acid directly in merchantable quantities by electrical discharges through confined portions of air; nor did I naturally refer to the vast deposits of phosphates which have been discovered in this country since the date of the papers cited, or to the possibilities of increasing our quantities of potash through the direct utilization of felspar rich in that material. These matters, however, are of such importance in this connection as to merit their extensive consideration.

EARLY STUDIES OF SOIL FERTILITY AND EXHAUSTION.

The exhaustion of the soil, to which reference has already been made, is a fact which was recognized and deplored by the earliest writers on agriculture in the United States. The methods of recuperating exhausted soil were also well understood in the early history of agriculture in this country, due to the fact that the methods used in old agricultural countries were well known by the immigrants. An essay was read before the Philadelphia Society for Promoting Agriculture, on September 28, 1786, by Mr. George Morgan, of Princeton, N. J. This was in competition for one of the prizes offered for the best plan of arranging a farmyard. This essay was devoted largely to the methods of collecting and utilizing the manure. In speaking of the importance of collecting farm manure for its fermentation, he says:

The earlier it is done the better. But it must be piled so high as that the cattle can not mount on the heaps, and care taken to mix the rich earths, mud, and marl well with the dung and litter. And if, after the first heaps remain a fortnight or a month, they can be turned over, or two heaps be thrown into one to occasion a new fermentation, the dung will be improved. When dung and litter are thrown into heaps without earth, they not only heat, but burn, and thereby suffer great injury in quality and quantity. After the heat has subsided the fermentation is over. If, when heaping your dung, lime can be procured, that is the time to add it in as large a quantity as you can command; but my situation is too remote from limestone to have this benefit.

By the time the whole is thus heaped, that first done will have undergone the proper degree of fermentation for carting out upon your Indian corn, potato, and turnip grounds, which I suppose to have been plowed twice or thrice. My aim is to spread and plow in 40 loads of 20 bushels each per acre; and, with the stock mentioned above, I can manure at this rate from 15 to 20 acres (according to the proportion of rich earths I cart in) every year. My calculation is about 200 loads of marl or rich earth as a foundation for my barnyard. I wish I could make it double that quantity. Gentlemen who have viewed my heaps of dung and my barnyard may form a judgment whether the quantity I mention is exaggerated.

The objections made to my method by common farmers are the expense and trouble of it; yet they allow every load of my manure, without lime, to be worth half a dollar on the spot, whereas it does not cost me one-third of that sum.

The attentive farmer need not be told to dig and wall a receptacle for the juices of his barnyard and to pump them over his dung heaps or carry them onto his grass. He will recollect and practice every means of benefiting his manure. The best method of constructing such a receptacle is particularly described and recommended by the agricultural society at Manchester. As I have not yet built one myself, I beg leave to refer to their directions.

The first premium granted by the society was for this essay, they having adjudged to Mr. George Morgan a gold medal, "The first premium granted by the society, as an evidence of the sense they entertained of the merit of his essay."

One of the earliest experiments in this country in the rotation of crops was that conducted under the auspices of the Philadelphia Society for the Promotion of Agriculture, by a Jersey husbandman, and printed in the Columbian Magazine, April, 1787. The scheme for promoting the increase of crops is as follows:

I have also laid out a field for a course of crops as practiced in England; it contains 12 acres, laid out, but not fenced off, in 3 acres each. The last harvest it stood in rye, and this autumn it has been plowed deep—some of it trenched. The following course is intended: Lot No. 1, to be manured next spring and sowed with barley; when up, to be sowed with 12 pounds of clover per acre and rolled in. No. 2, oats. Nos. 3 and 4, to be fallowed. The succession will stand as follows:

Year.	No. 1.	No. 2.	No. 3.	No. 4.
1786	Barley	Oats	Fallow	Fallow.
1787	Clover	Barley	Oats	Wheat.
1788	Wheat	Clover	Barley	Oats.
1789	Oats	Wheat	Clover	Barley.

And thus to continue in a succession of four crops, the stubbles always to be plowed up deep in the fall and laid in three-pace lands, and the barley land to be manured in the fall or spring before plowiug and sowed with clover, as above.

It would surprise an European to hear that the average produce of our wheat crops in this neighborhood is under 6 bushels; our farms are laid out in four or five fields, broken up with oats, corn, aud a great deal of buckwheat; next year fallowed; third year in winter grain; fourth year in grass, and some also the fifth year. This course leaves little pasture till the stubbles and meadows are opened, by which little manure can be made. No wonder, then, that our crops are light with such constant tillage aud scarce any help. The grain has not strength to stand the cold springs; much of it heaves out or is blown away with the March winds.

It is evident from the above that the system of cropping at that period was such as to favor the production of very little manure, and thus to progressively exhaust the soils.

The same author says further on:

I am also convinced that deep plowing, if not trench plowing, will be advantageous in lands much worn out by tillage without help of manure.

His further advice for improving worn-out soils was:

Besides breaking up in the fall, deep plowing and drilling, making composts of various materials, and green dressing with buckwheat should not be neglected; also liming where convenient.

In a work entitled "Arator," a series of agricultural essays, written by John Taylor, a citizen of Virginia, in 1813, it is stated, in speaking of the most effectual methods of fertilizing:

Manures are mineral, vegetable, or atmospherical. Perhaps the two last may be resolvable into one. Mineral manures are local aud hard of access. But the earth swims in atmosphere and inhales its refreshments. The vegetable world covers the earth and is the visible agent to which its surface is indebted for fertility. If the vast ocean of atmosphere is the treasury of vegetable food, vegetable manure is obviously inexhaustible.

This early prophecy of the neutralization of the atmosphere as a source of plant food has been verified by the progress of science.

which shows that the carbon dioxid with water and the nitrogen of the atmosphere are all abundantly used as sources of plant food. Again the author says:

It is yet a questiou whether the earth is euriched by any species of manure except the vegetable or atmospherical, and experiments have hitherto leaned toward the uegative. Without new accessions of vegetable matter, successive heavy dressings with lime, gypsum, and even marl have beeu frequeutly found to terminate in impoverishment. Hence it is inferred that minerals operate as an excitement only to the manure furnished by the atmosphere. From this fact results the impossibility of renovating an exhausted soil by resorting to fossils, which will expel the poor remnant of life, and, indeed, it is hardly probable that divine wisdom has lodged in the bowels of the earth manure uecessary for its surface.

The utility of red clover as a source of securing atmospheric fertilization was also fully recognized:

To draw from the atmosphere the greatest quantity of manure, to check the loss the earth sustains from evaporation during the process by shade, to give the manure the most lasting form, and to deposit it in the most beneficial manner are primary objects of the inclosing system.

The best agent known to us for effecting the three first is the red clover. Its growth is rapid; its quantity exceeds the product of any other grass; it throws up a succession of stems in the same summer; and these stems are more solid and lasting than those of other grasses. These successive growths constitute so many distinct drafts from the great treasury of atmospherical manure in one year. Whilst these drafts are repeated, the clover is daily securing the treasure, in a form able long to elude the robber evaporation, which it also opposes by shade. To its extracting from the atmosphere the greatest quantity of manure and elaborating it into a lasting form the most suddenly of any other vegetable cover, clover lays for wheat are indebted for their fame. Their success has been attributed to the portion of the vegetable in a succulent state, whilst it was owing to the greater portion which had arrived to maturity previous to the fallow. To ascertain this fact, let one moiety of a clover field be turned in as soon as its first crop flowers, and the other after the stem of the last crop is hard, and the whole sown on one day in wheat.

The peculiar propensity of clover to be improved by a top dressing of the gypsum is another striking circumstance of its affinity to the system for fertilizing land by its own cover. As its growth is suddenly and vastly increased by this top dressing, it furnishes reason to believe that the effect flows from a disposition communicated by the gypsum to the clover for imbibing atmospherical food by its external parts; and so much as it thus gains affords to the earth a double benefit. One, that this food, not being extracted from the stock of atmospherical manure possessed by the earth, does not impoverish it; the other, that being bestowed on the earth from whence it was not taken it adds to its fertility.

In regard to the sources of artificial manure he states as follows:

The most abundant sources for artificial manure in the most exhausted district of our country are the offal of Indian corn, the straw of small grain, and the dung of animals. We find in the two first proofs of the value of dry vegetables as a manure. If these few means for fertilizing the country were skillfully used, they would of themselves suffice to change its state from sterility to fruitfulness; but they are so egregiously neglected or mismanaged that we hardly reap a tithe of their value.

There is no farinaceous plant which furnishes so rich and so plentiful a crop as the Indian corn. It yields food in abundance for men, beast, and land. By the litter of Indian corn and of small graiu, and by penning cattle, managed with only an inferior degree of skill, in union with inclosing, I will venture to affirm that a farm may in ten years be made to double its produce and in twenty to quadruple it; the ratio of its increased value is, of course, still greater.

There is no other secret in the business than that none of these manures be wasted. The agriculturist who expects to reap good crops from neglecting his manures is equally a fanatic with the religionist who expects heaven from neglecting his morals.

In regard to the combination of manures the author says:

Gypsum, clover, and inclosing, working in conjunction, have within my own knowledge doubled, trebled, and in a very favorable soil quadrupled the value of land in the space of twelve or fifteen years; whilst the land regularly produced two exhaustive crops—those of corn and wheat—in every four years of the period, and these crops were continually increasing.

Of lime and marl we have an abundance, but experience does not entitle me to say anything of either. About a family, a variety of manures may be thrown together and form a small store for gardens and lots. Among these, ashes deserve particular attention. Like other manures, they suffer by exposure and evaporation, but less, because water is a menstruum which will convey much of their salts into the earth if they are spread; the same menstruum conveys most of these salts out of the ashes if they are exposed to it before they are applied as a manure. Hence, when ashes have not been reduced by water in richness they are to be used as a manure more sparingly; and when they have, more copiously. In their unreduced state just from the chimney, when sprinkled an inch thick on the long litter and dung from a recently cleansed stable, they constitute the best manure I have ever tried for asparagus. The beds are well forked up in the fall, covered two or three inches deep with the unrotted stable manure on which the fresh ashes are placed, and so remain until they are thrown into proper order in the spring.

The effect of tobacco on the land is graphically described by the author in the following words:

Though its profit is small or nothing, its quality of starving everything exceeds that of any other crop. It starves the earth by producing but little litter, and it starves its cultivators by producing nothing to eat. Whatever plenty or splendor it may bestow on its owner, the soil it feeds on must necessarily become cadaverous and its cultivators squalid. Nor can it possibly diffuse over the face of the earth or the faces of its inhabitants the exuberance which flows from fertilization nor the happiness which flows from plenty.

The first account I can find in this country of the use of marl as a fertilizer is in a letter read before the Philadelphia Society for Promoting Agriculture on December 9, 1806. The letter was written by Josiah Reeve, of Rancocas Creek, on the 20th of November, 1806. It is called a "new mineral manure for clover." Mr. Reeve describes the manure as follows:

The black sulphuric substance by us called marl is found in great abundance through most parts of the country in a northeast and southwest direction from the headwaters of Crosswick's Creek, in Burlington County along on the upper part of nearly all the creeks from thence to the southern part of Gloucester County; we find it in the banks of streams and in most places at the bottom of many of our wells, and it often spoils the water. On my farm and through our neighborhood it abounds near the surface in the meadows and generally in the banks or hillsides, about from 4 to 6 feet below the surface; the depth I can not, from experience, say much about, but from the observations of others find it varies from 6 to 15 feet and more. I have at thy request brought with me to the city for thy use a box of it, of which I wish thee or thy friends to make a chemical analysis. The result of my own and my neighbor's experience is that for grass lands about 10 two-horse loads to the acre—laid on the surface in the autumn—is better, if the next season proves moist, than double the quantity of any other manure and will last longer, changing in two years rough bound meadow into almost clear white and red clover; but the last dry summer it did very little good. I am in the practice of mixing in my barnyard or in the compost heap the marl with the dung, two loads of the former with one of the latter, and always find when put on my fallow that it is as good, or better, than the same quantity of dung alone, and much better for the clover that follows, but in its crude or raw state does not do on grain the first year, except for Indian corn, which some say it helps by laying it on the tops of the hills in the spring. I put some in my manure for my garden and found it made the clover grow among vegetables so spontaneously that we have had much trouble to destroy it ever since.

The above description shows an admirable use of the marl in composting with barnyard manure, and describes the general effects of this marl upon the soil in England, which is easily recognized as descriptive of the same effects to-day. The use of marl or chalk has been practiced from the earliest antiquity in agriculture. In the north of France I saw a number of deep hollows in the otherwise level fields, and was told by the inhabitants that they were ancient marl beds which were used at the time of the occupancy of Gaul by the Romans. The utility of marl in restoring fertility of the soil consists largely in its neutralizing effects produced by the decay of vegetable matter and by its mechanical effects in percolating clay, and thus rendering the soils more porous and spongy. Its efficacy in promoting the growth of clover, as was seen, was known by our farmers more than one hundred years ago.

Another valuable article on the utilization of lime in the improvement of the soil is found in a letter read to the Philadelphia Society for Promoting Agriculture on December 8, 1807. The letter is so interesting that I give it in full:

IMPROVEMENT OF LAND.

CHESTER COUNTY, *November 20, 1807.*

FRIEND VAUGHAN: Agreeably to your request, I now inform you how I have improved my farm. The first three years I could only keep 2 horses and 2 cows, and seldom had more than 4 tons of hay, though the last six years I have grown from 20 to 25 tons a year. Had I taken your advice when I first took the farm, it would have thrown much in my way—that was, to use lime on my land. When I determined to try it, I first got 200 bushels and laid it on 9 acres, planted with Indian corn, and had as great a crop as had been ever seen growing. My neighbors came far and near to see it. The year after, I made a fallow of the land, put in wheat on 3 acres and the rest in rye, and had a good crop. In the spring I sowed it with clover and timothy and put 2 bushels of plaster of Paris on an acre, and had as great a crop of clover as could grow; it laid three weeks before the time of mowing. The lime and plaster did all this, for no land could be poorer before. There are 10 acres in the field, and not being used to spreading lime I laid it on 9 acres; where I laid no lime I got no clover, although I put on the plaster. I have limed all my land and plastered it every year, and never fail of clover. I think 2 bushels of plaster are enough on 1 acre. In one field I have put on 4 bushels on half and 2 on the other half, and I find no difference in the produce. There is another thing in which I was wrong in not taking your advice, viz, not keeping oxen instead of horses. This spring all my horses became sick, and I was forced to buy a pair of oxen. I supposed I should be tired of them, but, on the contrary, I am tired of horses, as I find that with my 2 oxen I can do more work than I could with 4 horses, and with half the expense. I have worked horses for forty years, and if I had used oxen in their place they would have put £500 in my pocket. My oxen go to the limekiln once a week—21 miles—in the morning, and return the next day, in the afternoon; after resting two hours they go to work; horses can not do this. There is another thing I find advantage in. I cut all my cornstalks and carry them to the barnyard for litter; when well trodden I cover them with lime and then add another layer, then more lime, and so on until all the stalks are used. In the spring the stalks are all rotted, and I have no trouble in turning them up. Last spring I had 176 loads of dung. The first three years if I had 20 or 25 loads it was a great thing. My neighbors thought me crazy to buy lime and to be at such expense, but now they are all falling into the same way.

I plow all my land in the autumn for corn, and in the spring lay on the lime, plow it all over, harrow it down, and never am troubled with cutworms or weeds. I find the fall plowing is a great advantage.

Your affectionate friend,

(Signed) WILLIAM ASHFORD.

JOHN VAUGHAN,
Member Agric. Soc. Philad.

The secretary of the society adds some important comments on the letter, stating, among other things, that it is published "for the encouragement of those who live on worn and exhausted lands." Some of these claimed that they could not procure manure, that plaster was not sufficient, and that lime was expensive. An important point, however, is emphasized, viz, "that the mixing of lime while the vegetable substances are putrefying is a mistake. It had better be put on the land, or if it must be mingled with the manure, let it be after the fermentation is over." This is in exact harmony with the present understanding of the fact that lime frees ammonia and thus produces a loss of valuable nitrogen.

The advice given by the Philadelphia Society for Promoting Agriculture to farmers of worn-out land is so interesting that I give it in full:

1. If no water be in your barnyard, dig a well; and confine your stock from November to May, never permitting them to wander after water, or the provender of the stalk field, in which they empty themselves and scatter their dung, instead of filling themselves, either for profit or economy. Let not a hoof unnecessarily leave your yard.

2. Haul into the yard every putrescible substance you can get, and when proper, clean up the yard, and have a pen for your manure, both from the yard and stables, inaccessible to cattle or horses, whose poaching or treading prevents fermentation and is highly injurious. Mix earth with your litter, rather than lime.

3. Plow your fields in the fall 7 inches deep, but plow no more than you can manure, and let the rest lie waste till you can do it justice. Buy lime; if you can not reach 2 acres be content with 1. Move your fences and plow up their sites. Mix leaves, weeds, and all putrefiable substances in long and low beds, so as to be turned by the plow and become excellent compost. For this purpose also go into your woods and with leaves and wood soil make beds of compost of these materials, as well as of the mold in low places into which it has washed or has been deposited by ponds of water or rains and floods.

4. Lime your fall-plowed fallow with 40 bushels to the acre. Plant Indian corn; put compost on the hills and plaster the corn.

5. After the corn is gathered cut your stalks and haul them to your yard. Plow again for a winter fallow. Your plowing (except for seed) should never be less than 5 to 7 inches deep.

6. In the spring harrow in buckwheat, to be rolled and plowed in when in full blossom with an East Jersey plow without a coulter, or any other that will not choke.

7. Put on what dung you have made and plow it in with your seed. Your compost will now be fit for top dressing your wheat, which is to be the crop of this year; and sow no more than you can manure.

8. On the wheat sow clover seed, and the succeeding spring plaster the clover. All this can be accomplished in two or three years. When you have perfectly learned this alphabet you will get into habits that will enable you to teach instead of requiring instruction.

9. When your old fields have inert vegetable matter (as is the case with most old fields) plaster them to throw up pasture, and increase your stock by this additional subsistence.

10. Never sow in a foul or weedy fallow to save a plowing, or on a wet one to save time. Avoid oats and exhausting crops and never stubble in or let one chaffy-husked or culmiferous crop immediately follow another.

11. Change your crops and destroy weeds, or they will destroy you; turn a foe into a friend by turning them into manure. Explore your own and the neighboring farms for marl, clay, peat, earths, or substances for experiments on your fields. Be not discouraged by failure, but persist in essays on a small scale till you succeed.

The use of lime and its value in preserving and increasing fertility is further illustrated in an article in the Annals of Agriculture and Other Useful Arts, published by Arthur Young, London, volume 2,

1784. This is found in an account of a fortnight's tour in Kent and Essex, page 39:

The circumstance in their husbandry most deserving attention is the use of chalk as a manure. They bring it all from Malden, at the distance of 6 miles; it is brought by sea from Kent, and a wagonload costs at the quay 10s. The method employed is this: The teams of five horses and a wagon and two men go out about 12 at night, load at Malden, return, unload, bait, go again with the same wagon and horses and return and unload and all over by 1 o'clock at noon. This is, I think, the severest work I ever heard of; 24 miles with so heavy a load, twice to be loaded and twice unloaded by the same men, yet it is here common; they reckon that every load costs in the whole 20s. They lay from five to eight on an acre, either upon a clover lay while feeding, or on a summer fallow; the effect exceeds anything I have met with; a very thin dressing of it is seen immediately to an inch, like rotten dung, and lasts twenty years; fifteen in great heart. Mr. Cott showed me from his garden a field of wheat hanging on the side of a hill at the distance of half a mile, one part of which was evidently much inferior to the rest which was in general laid; that part was the only spot not chalked, the farmer not having time to finish the field; he was present and confirmed the account. The same farmer (Mr. Parkinson, of Brackstead) having chalked a field, brought some in a cart as they returned from the field, and spread it thinly on one spot in a piece of poor, dry land; the whole was sown with turnips; during the whole season from their coming up that spot was to be seen at a great distance, and the roots were far larger than anywhere else.

They think their lands will do nothing without chalk, insomuch that the whole country will, in a few years, have all been chalked. The soil on which it does such wonders is loam; they have very little clay and no sand. On gravels the effect is but slight; it is the good sound loam in which it answers like the richest dung.

It is a general opinion among them that land which has once been chalked will not take it again, and this opinion seems to prevent the trial; they acknowledge, however, that mixed with earth and dung it is even then excellent. A very particular circumstance they have observed is that laying a slight dressing of chalk and earth or dung on a field never chalked will take so much effect that the same field will not then answer to chalk completely. Another remark they have also made is that the chalk presently gives the land a red color; so that a part of a fallow that has been chalked will, from the tinge, be discernible at a distance.

Upon my asking Mr. Parkinson if they ever laid chalk upon meadows, he replied they did not require it, besides, they supposed it would do harm as they observe that it is a strong enemy to grazing; that is, to the ground covering itself with good grass. A field which before chalking will run of itself to a fine head of white clover no longer does it after chalking; this is very remarkable, for one would suppose what is manure for corn would be so to grass.

The chalk is not soft, but rather hard; the sharpest frosts leave very many lumps unbroken, so that they break them with pickaxes; and the hard bits that break to a clear white they say come from the bottom of the pit and are esteemed better than the pieces which crumble between the fingers. I tried some pieces at Mr. Cott's in vinegar and water; the effervescence with the former is pretty considerable, though not near equal to what I have seen; but in water it falls very slowly, if at all.

Some farmers have tried lime, and with great success, upon the soils proper for chalk; this is a fresh instance that the excellence of these manures much depends on the soil whereon they are laid; on good loams they take full effect, but on poor lands they find nothing to work on. About Ensield the same chalk does wonders, which at North Mims has very little effect; the one is a rich loam, the other a poor gravel.

An interesting account of air as a plant food is found in the Annals of Agriculture and Other Useful Arts, published by Arthur Young, London, 1786, volume 1. In this volume, on page 169 and following, is an account of some attempts to apply air as a manure to the soil:

The theory which our great philosopher started, that phlogiston is the food of plants, appeared to me so important in the philosophy of agriculture that it eugaged my earnest attention. It has never been my conduct to abandon to speculation that which can be brought to the test of experiment. But a person in such retirement as I live iu, without opportuuity of communicating with practical chemists and philosophers, with smaller means of overcoming difficulties by force of large expenses, and without experience in the sciences necessary to pursue such inquiries, far from all other assistance; a persou thus situated may feel very earnest desires to pursue a line of activity and vigor, and yet experience the mortifying conviction that, for want of better support, his wishes may be in vain and his efforts useless. Many of these feelings have been miue through this little beginning of my inquiries; imagining a multiplicity of experiments which I had not the power to execute.

Being desirous of knowing what were the discoveries on which this theory was founded, I read the five volumes of Doctor Priestley with attention, and also Doctor Ingenhouz's experiments on vegetation; aud I was exceedingly surprised to find that, amidst a great career of experiments that may indeed be called a new world for the ingenuity of mankind to rauge in, though the trials were numerous and decisive which prove the power of plants to imbibe phlogistou from impure atmospheric air, yet those which show it to be taken in as a pabulum or food are very rare. Even in the most remarkable of Doctor Priestley's, the willow plant thriving best in inflammable air, an instance is given in the same page of mint thriving much worse in it than in common air. Aud in a letter which I had the honor of receiving from him upon this subject, July 1, 1782, he expresses himself thus: "Though I have no doubt but that phlogiston is the essence, as we may say, of the food both of plants and animals, they are not capable of extracting it except from certain substances aud in certain circumstances; aud phlogiston administered iu any other way infallibly kills both." The doctor means, I apprehend from other expressions in his correspondence, that the phlogiston must be given either as the result of putrefaction applied to the roots, or else in air applied to the leaves, in which I entirely agree with him. The labors of that truly great man are almost universal; a reach of sagacity, a depth of penetration, united with an ardor, and even enthusiasm, in pushing his researches with an unremitting industry that removes difficulties in the very moment of discovering them, would have left us nothing to wish in the present inquiry had it been possible for oue mind to bring to maturity the ideas he has throwu out for the employment of thousands. The variety of his pursuits has prevented so marked an application of his discoveries to my favorite art as might otherwise have happily advanced it.

If there are any experiments extant in which the express application of phlogiston, or of inflammable air, to the roots of plauts as a manure has been made I am ignorant of them. No such application, or even conjecture of the result, appears in any work that I have cousulted; and yet it seemed to be the only method by which the question of that substance being the food of plants could possibly be decided. The effect of it on leaves, from the experiment of Doctor Igenhouz, seems rather to be an edulcoration of impure air for the purpose of making it salutary to the human body than necessarily beneficial to the growth of the plant. If this is not the exact result, I may at least observe that the doubt which arises might be very easily resolved by those who have the skill and apparatus necessary for such experiments.

The leaves of a plant may perform the office of lungs in the body of an animal, and inflammable air may be as salutary to their inhalation as dephlogisticated air is in the respiration of animals; but it no more follows (however likely it may otherwise be) that phlogiston is therefore their food than that pure air is the food of man.

Following this are records of a number of experiments, and the conclusions are given on page 184 and following:

Many of the preceding experiments may, perhaps, be found to open the way toward a more consistent theory of vegetation than has yet been established. Had not inflammable air been tried the leading feature for selection would have been the effect of the volatile alkali, which is uniformly excellent aud, as putrefaction is known in common practice to yield admirable manure, it might have been concluded, with great propriety, that the volatile alkali was the food of plants, a theory for several years the favorite deduction of my practice. But inflammable air haviug so decisive an effect, analyses, if I may use the expression, of that alkali show us to which of its parts we are to attribute the result, viz, phlogiston in a volatile state.

The volatility of the element seems essential to its action on vegetation for, in a fixed state, it appears to be attended with little or no effect, and in most cases with a mischievous one; for, though charcoal operates considerably as a manure, yet the white ashes of that body being almost uniformly superior to it will not permit us to attribute the effect to its phlogiston. We are rather to suppose that it operates mechanically in the manner of wood ashes. Pitch, tallow, red lead, sugar, and powdered flint are poisons; these substances abound greatly with phlogiston, but not in a volatile state. It is very remarkable that in the form of a liquid it is mischievous unless in the volatile alkali; not only in spirits of wine, but in that most volatile liquid of all others, ether. Oil of every kind the same, and in general let it be mixed with what it may; a circumstance the more remarkable, as a very ingenuous physician (Doctor Hunter, of New York), for whom no one has a greater respect than myself, actually fixed an oil rendered miscible with water as the food of plants. Keep that mixture, or any other substance in nature capable of putrefaction, till it is putrescent, and I have no doubt but you have the food of plants. Why? Because you then have phlogiston in a volatile state.

Still, however, spirit of wine being so prejudicial, surprised me a good deal till I found it was generally considered as composed of an acid united with phlogiston. All the three mineral acids are uniformly poisonous to vegetation; the acid is, therefore, prevalent enough in the spirit of wine to act in its usual manner. Sulphur also has always been a poison, though in some instances it has seemed to act for a short time as a stimulus. Fixed air proving in any case beneficial surprised me, for if the food of plants depends on the volatility of phlogiston the result of putrefaction (which is the fact in nineteen instances out of twenty) then every antiseptic ought to be pernicious (not to mention the proof Mr. Bewley gives of its being an acid). We must, however, remember that the benefit of it in the preceding trials is by no means so well ascertained as that of inflammable air.

To discover facts hitherto unknown in science can hardly fail of being useful in the end, however deficient in that respect they may appear at first. The inquiry is worth the pursuit, though not immediately applicable to the practice of any art. But, in the present case, we can scarcely take a step that is not nearly connected with common agriculture. If phlogiston in a volatile state be the food of plants the farmer has a lesson of infinite importance to him; to acquire and cherish as much as possible the effects of putrefaction and consequently to manage his dunghills and other receptacles of manure in such a manner as to prevent the escape of the volatile principle generated by the putrescence. In this view the practice of frequently turning dung over, which is reckoned by some writers so very excellent, will, perhaps, be found after one stirring uniformly pernicious and tending only to let loose and dissipate in the atmosphere the essence which would most contribute to the fertility of the fields. Without a certain degree of putrefaction the phlogiston will not be volatile; continued too long it will all fly off. Consistent with this theory is an observation I make every year in my own farmyard. I have a standing sheepfold, part covered and closed and part of it uncovered; the whole is littered equally, but one load of the dung in the covered part is worth two in the uncovered. When the carts go in to be loaded it stinks much more offensively and makes the men's eyes water that move it. This shows that the volatile alkali and phlogiston are retained and that the action of the sun and atmosphere is to carry them off.

I wish much to have made some progress in deciding the effect of sunshine on soils, but, except the experiments on earth kept seven years excluded from both light and sunshine and also kept in a vault, I have not been able yet to execute the trials I have projected, though some of them are at present in course. Those were decidedly against the soil imbibing any food from the action of that luminary, and the whole range of common husbandry seems to speak the same language. Covering the soil with a thick, smothering crop of clover, tares, pease, etc., is found to enrich it far more than a summer fallow. Old meadow land receives very little of the sun's rays, and some woodlands none, yet these are the richest soils all over the world, because the putrescence of vegetable and animal matter impregnates them with volatile phlogiston. I can not conclude these experiments without admitting an imperfection for want of more spirited and extensive trials (many of which I had planned), but the expenses necessary are beyond my ability, and no day passes without my regretting that insufficiency for pursuing the hints that arise. Time is precious.

Life flies fast away, and leaves one little more than wishes to execute what fortune forbids. I should be glad to try electricity by means of a machine constantly turning by wind or some other power. I want a very lofty conductor to bring down the electric fluid from the clouds, to impregnate certain recipient bodies, with and without plants growing in them. I wish—but wishes are vain and unworthy every philosopher; experiment is his business; we must content ourselves with doing the little in our power.

The question of lime was again considered in a communication read by John Lang to the Philadelphia Society for Promoting Agriculture, on August 9, 1808, and published in the second volume of the Memoirs, page 1 and following:

We have for some time past heard much talk about two varieties of lime, the one useful or favorable to the growth of vegetables, when used as a manure; the other hurtful or pernicious, and therefore not to be used for that purpose; the first is termed calcareous, the other magnesian lime.

The first notice we have of this magnesian lime is from a communication of Mr. Tenuant, published in the London Philosophical Transactions.

This is doubtless a subject of great importance to farmers and, in my opinion, deserves to be more fully investigated. If all lime which contains magnesia is only useless as a manure, it must be of great importance to our farmers to be informed how they may be able to distinguish this from the calcareous lime; but much more so if it is, as Mr. Tennant says, destructive to vegetation, and that it diminishes the fertility of the soil. The distinguishing characteristics of these two varieties of lime mentioned by Mr. Tennant, it would seem, cau only be discovered either by analyzing (which process farmers are generally ignorant of) or by making experiments by applying it to the soil. It is said that magnesian lime when used in too great quantities reuders the soil less fertile, and wherever a heap of it has been left on one spot vegetation will be prevented for many years; while of the other sort of lime, a large quantity is never to be found injurious, and that the spots which are entirely covered with it become remarkably fertile instead of being rendered barren.

From the above statement it would appear that by far the greatest proportion of all the limes used either in this country or in Europe are of the magnesian kind, or in other words must contain a certain proportion of magnesia. For my own part, I have never seen pure calcareous lime, unless that made from calcined shells may be denominated such; though I must own I am not chemist enough to be able to discover the magnesian lime, except by its effects upon the soil, as above described by Mr. Tennant and Doctor Darwin. The distinctions which some farmers make of hot and mild lime, Mr. Tennant believes to mean magnesian and calcareous lime. And the Doctor says he is informed that the magnesian lime is preferred in architecture, and is said to go further in making mortar, etc. If this is the case I think it will be admitted that all the lime used in the United States, either for building or manure, is of the hot or magnesian kind; as it is well known that the lime of this country is generally stronger and of course will go further in making mortar, or as a manure for land than English lime. Were our farmers in this country to discover lime of so mild a quality that thistles and grass would grow up through the sides of the heaps of it, but at the same time it would require three loads of this lime to produce the same effects upon their land as two loads of the lime now in use, I think they would surely prefer the latter to the former. Our farmers know very well that wherever they lay their lime heaps every particle of grass or other vegetables will be destroyed; and that the spots on which it lay will not bear any crop for a year or two after, unless they are careful to remove it so clean that no more shall remain on these spots than the same proportion which they spread over the rest of the field. They likewise know that if they should leave their lime heaps exposed to the influence of the atmosphere, to successive frosts and thaws, rains and snows, etc., it would in time become as mild as the calcareous lime destroyed by Mr. Tennant. But then it would be useless for mortar, and for land it would be like some medicines of which the chief recommendation is that if they do no good they will at least do no harm; and for that reason they comnonly cover the heaps over with sods, or straw, etc., till the land is prepared for putting it on. Our farmers likewise know that poor land will not bear so much lime as rich land, and that if they should by mistake over-lime their land, the succeeding crops will rather be hurt than benefited by it; and in such cases there is no remedy but either to give tbe field a dressing with dung or let it lay a year or two till the heat of tbe lime is partly given out, and then it will have its effect. From this I conclude that lime must act as a stimulant, and that the quantity applied to the laud ougbt to bear an exact proportion to the carbonic, or vegetable matters contained in the soil. It is well known that stimulants used iu small quantities are in some cases very useful in the animal ecouomy, but in great quautities they will destroy auimal life.

I would not by any means presume to call in question the results of Mr. Tennant's or Doctor Black's experiments; on the contrary, I am rather inclined to believe that all stone lime contains a greater or lesser proportion of magnesia; but that the lime which coutains the greatest proportion of that earth is totally unfit to be used on land as a manure, I think deserves a second consideration.

Doctor Darwin observes that the substauce called chalkstone is almost wholly magnesia; now I know from experieuce that chalkstone land is the most kindly to all sorts of grain of any soil I am acquainted with, and will bear a longer succession of severe cropping before it is exhausted. But perhaps it is the process of calciuatiou which gives to the magnesia that caustic quality which renders it so hurtful to vegetation, as Mr. Tennant found by his experiments, that 30 or 40 grains of lime did not retard the growth of seeds, more than 3 or 4 of calcined magnesia. From wbich Doctor Darwin concludes that, as both injure vegetation in large quantities, they may both assist vegetation in small ones.

Consistent with the doctor's remark I would just observe that there are many substances wbich make rich manures wheu used in small quantities; for instance, I have seen very great crops of barley got by sowing the land with pigeon's dung, as thiu as we sow rye, and harrowing it in along with the seed barley; whereas had it been put upon the land as thick, or half as thick, as we would put stable or barnyard dung, it would as effectually destroy all vegetation as hot lime used to excess. The same remarks will apply to the dung of all kinds of domestic fowls, also to human dung and urine, so much valued in China. Commou salt has often been recommended as a great assistant to tbe growtb of vegetables wheu used in small quantities, whereas it is well known that tbe excessive use of it will render land totally barren.

It will be admitted on all hands that all animal and vegetable matters coutained iu the soil must undergo a decomposition by some means or otber, so that being thereby reduced to such a state as to be easily soluble in water, they may be readily absorbed by the tender roots, by some termed the mouths of plauts. That the roots of plants naturally possess to a considerable degree the power of producing this decomposition, I have had occasion more than once to observe, in tbe case of plantiug potatoes with woolen rags instead of dung. I have seen fiue crops of potatoes raised by dropping a small piece of woolen rag, not larger tban the hand, in tbe furrow along with every set of the potatoes when planted, and I have observed when the potatoes were gathered in the fall that, in every instance where a potato plant bad failed to vegetate, the rag was turned up entire, very little damaged by being buried under ground; whereas, on the other hand, not the smallest vestige of the rags were to be seen in any part of the ground where the plants had succeeded and grown to perfection. Only I observed in some instances where the rag had been uncommonly large, a white moldiness upon the soil about tbe roots of such plants, which seemed to me an indication that more nutritious matter had been formed than could be absorbed by the roots. Besides I observed the palms or tops of such plants were always large and of luxurious growth, while the potatoes at the root were small and not fully ripe.

But there are other animal and vegetable substances which require more powerful solvents to prepare them for tbe food of plants; such substances must be decomposed either by means of the putrid fermentation, or by the application of hot lime, etc. But while the putrid fermentation is going on, it is exceedingly noxious to vegetation, as we may see by the bad effects of putrid or stagnant water upon the roots of tender plauts; while on the other hand, hot lime will cbeck the progress of putrefaction, aud at the same time very quickly effect the decompositiou of various bodies; thereby preparing sweet aud wholesome juices, whether they consist of carbon, pbosphorus, oils, or alkali, or compounds of all or either of these. And I conceive if tbe lime meet with a sufficient quantity of such substances as it in this manner acts upon, it will, by mixing with such juices, thus prepared, be thereby deprived of its caustic quality in tbe same or somewhat similar manner to that whereby magnesia or cbalk blunts, or sheaths, the points of tbe sharp particles of acids. But if the lime does not meet with a sufficient quantity of carbonic or other matters in the soil to act upon, so that its caustic quality may be completely overcome, then in such case it will act upon the tender roots of the growing plants, in the same manner as it acts upon grass or other vegetables when laid in heaps on the surface. And this is in my opinion the cause why lime in some instances is hurtful, instead of being beneficial to land.

Upon the whole. I think instead of troubling our farmers about distinguishing the different qualities of magnesian and calcareous lime, it will be better to advise them to use lime sparingly on poor land, and at the same time to use every exertion to increase their dung and compost heaps, whereby their land will be prepared for the application of lime, not only with safety, but great advantage.

An interesting article on the improvement of soils is found on page 187 of the Memoirs of the Philadelphia Society for Promoting Agriculture, volume 2. The communication bears date of March 9, 1810:

It is generally acknowledged that the best land may be reduced to sterility from an injudicions rotation of crops. It remains in a great measure to be proved. whether a farm, which from bad management had been rendered barren, can be restored to its pristine fertility, by a treatment, not beyond the reach of every farmer (nor without the farm) who possesses the land, free from incumbrances, which are nearly equal to the supposed value of his worn-out farm.

When an inquirer examines the publications of those who have given the results of their experiments, it appears not only practicable, bnt easy; frequently, however, some circumstance is not mentioned in the communication or something not attended to by the reader who intends to make the same successful experiments, but fails, from the causes stated.

The Rockland farm exhibited a subject for experiment, as it had not only been reduced by cropping, but generally, became a common for every animal to take what remained of the scanty natural, but coarse, herbage; having read in various books the results of sowing plaister and clover, it was presnmed that sowing plaister and clover would be the extent of the expenses required to fertilize the fields in a few years; a few experiments proved that the plaister and clover seed were both lost, as no one could at any season of the year point out what field or upon what part of any field they had been deposited, unless where the briars and bushes had been eradicated.

It should, however, have been mentioned that the soil was generally a cold or heavy clay, some blue, white, light brown, and a few spots of red clay, loaded with hard blue stone and rocks, chiefly quartz, mixed with iron and copper. Some of the experiments were made with plaister, others were made by top dressing with lime, at the rate of 25 to 30 bnshels per acre; the lime was brought 20 or 25 miles from the kiln, and laid on the field at 25 cents per bushel; it was formed into a bed of about half a foot thick and covered with earth, plowed and thrown over it, before it was slacked, that all the phosphoric principle disengaged by the water might be united with the earth which covered it; a heavy harrow was afterwards passed over it, so soon as the shell was reduced to powder; the bed of lime and earth was then frequently turned by the plow and harrow until the whole assumed the appearance and smell of soapers' ashes, containing about 10 parts of common soil to 1 of lime. It was then carted and spread regularly over the field, and in every instance it gave a return of clover equal to 10 loads of stable manure to the acre. The idea of mixing the lime and earth was suggested from spreading the refuse mortar of lime and sand gathered from about buildings and laid upon the field, the effect of which I observed was more immediate than any equal quantity of lime; though mixtures of lime and earth were eqnally so, in both cases the lime was completely pulverized, and the sand and earth broke np the communication of lime with lime, and the succeeding rains carried the fertilizing principle of the lime, as from a sieve, into the soil where it was spread; it completely divided the soil, rendering that open and warm, which before was compact and too cold for the roots of the grain to live in.

The whole soil, which before felt dead under foot, became so elastic that persons of observation, by walking over the field in the night, distinctly told how far the lime and earth compost extended. The color of the soil was likewise changed into that of chocolate.

These effects presented several ideas which had not occurred to me before, viz: That anything which would separate the particles of the soil and admit the air would render these cold and heavy clays warm and fertile; that the free intercourse of air would carry off the acid. To meet this, plowing in the fall was adopted and found successful. One-half of a field six years ago was plowed in the winter, the other half plowed in the spring. That part which was plowed in the spring has never brought grain or grass equal to the other. It should have been observed that the field had not been plowed for upward of twenty years, and of course a great body of rubbish and roots were plowed in after the briar hook and grubbing hoe had smoothed the surface. Spreading of manure in the autumn from the compost bed has also been introduced with universal success, both upon grain and grass fields, the lye or salts of the manure being carried into the soil by the rains upon the breaking up of the frosts, which have in some measure prepared the soil to receive it. High agricultural authorities, even bottomed on accurate observation, are opposed to the practice of spreading out manure in autumn. Amongst these we find the justly celebrated Lord Kaims, in his Gentleman Farmer, a work upon first principles, and deservedly of the highest authority. A departure from his judgment is only to be allowed where facts would censure silence; nor should his name have been mentioned unless to avoid the charge of writing without attending to what has been said on that subject. It is no conclusive objection that "the strength of the manures will be carried off by winter rains or exhausted by the frost." Are not the warm showers more so, and are not the exhalations more copious in a warm than in a cold temperature? Is the descending of the sap in trees no monitor as to the season for spreading out manures, and about the operation of nature for renewing and invigorating the process of vegetation?

Briar bushes and all vegetable substances have been covered up with earth, rotted, and used with the same success as stable manure, and so far and so long as they separate parts of the soil and admit the air they fertilize and change the color of the mold. These experiments, tested by frequent repetition, have laid a foundation for experiments less expensive and equally fertilizing for the production of grass and grain. Plowing and sowing for the purpose of producing pasture and accumulation of vegetable soil have been adopted. For this purpose wheat, rye, Indian corn (maize), buckwheat, and oats have been sown upon fields plowed, which were incapable of producing any crop. None of those grains have produced pasture and vegetable soil equally valuable to that from the oats. Where the others have failed its roots have pierced, disarmed, and vanquished the inhospitable soil and rendered it fertile. The winter plowing is continued and the oats are thrown in as early as the season will allow, sometimes even in February, either upon what has been plowed in autumn or in the fields which were in corn the preceding year or in pasture oats the preceding fall. In general they afford early pasture, and when they are replowed in July and August and sown again with oats they furnish excellent pasture from early in September until late in December, during that season when all other pasture is generally dried up. The first sowing of oats only gives about two months' pasture, but the roots and remaining herbage afford a manure for the second sowing, and this always yields four months' valuable pasture, which no other course known to me will afford. In September, October, November, and December considerable attention is required to preserve the young clover which the field will be able to raise in the second year of the oat pasture. If sown with the oats in the spring, the cattle should never be put in while the ground is too moist, as they would destroy and tread it into the soil; and sometimes dry seasons are also highly injurious to the clover. When the clover is sown with the second sowing of oats the same care is required to prevent its being trodden in by the live stock. For this purpose it is always necessary to have a spare field of old pasture, which they will feed upon in wet weather and which they would not relish in dry weather. To guard against a dry season it is most proper never to pasture the oats where the clover is sown so much as to prevent the herbage of the oats from giving shade to the clover. So soon as a field will produce clover luxuriantly, there is no farmer at a loss how to make his field as rich as he pleases, and having got them into good heart, it will be to his interest to put them in such rotation as shall increase the vegetable soil and consequent fertility of his fields.

It is almost unnecessary to mention what will make its way to the understanding of every farmer, viz, the many advantages gained from treating his barren field in this way.

1. Early and late sweet pasture from such fields which otherwise produced a scanty, coarse herbage unpalatable to every animal.

2. Immediate reward for his labor; the stock are supported by it within two months from the time seed is sowu; the two returus give six months' green food; he is not, however, to depend upon it for all his summer pasture.

3. Perhaps it is one of the most effectual means to root out garlic, because what have escaped the plow in the spring are eaten down with the pasture from the first sowing of oats and prevented from going into seed; the plowing in July and August expose so many of its bulbs to the sun that few shoots are to be found in oats sown for fall pasture.

4. It is an easy and profitable way of clearing grain fields from every species of injurious weeds, as it will convert them iuto vegetable soil and enable the farmer to raise whatever grain or grass he shall judge most suitable to the soil.

5. It will save the expense of a fruitless summer fallow, and the green herbage will aid the dairy.

6. It enriches the farm from within itself, aud no expense is required beyond the reach of any farmer; by rising one hour earlier, and working one hour later than usual, for two weeks, he may plow and sow 2 acres, as an experiment. The pasture will recompeuse his labor, while his soil is greatly improved; it is equally evident that the fertility of the soil is acquired partly from the roots of the oats opening the soil aud introducing the air and warmth of the sun and partly from accession of vegetable soil produced from the decomposed roots of such pasturage; but even before the roots are couverted into soil they produce the most beneficial effects. Those from the spring sowing retain the moisture and supply the summer sowing with it. The roots from the fall pasturage, being full of sap, iutroduce winter frosts everywhere into the soil, which, swelling with the cougealation, separates the particles; for it is to be observed that roots, while the stem is eaten down by the stalk, do not become hard, but are more numerous thau when the plant is matured into grain. It is however necessary to sow at least double the quantity of seed to that required for crops of grain, the pasture being so much the thicker and the increase of vegetable soil from the decayed roots so much the greater.

It is not to be expected that one or two repetitions of the series of oat pasture will make the soil equally rich as a common dressing of stable manure, which from a farm of 100 acres will not in general extend over more than 10 or 15 acres; this gives to one acre nearly the vegetable soil produced from 7 or 10 acres. It is to be remembered that the object proposed was to render worn-out or barreu fields productive; and in no case have I found a field which was not after two years, oat pasture capable of producing clover and receiving the gypsum with evident advantage. So soou as a field produces clover no one is at a loss how to produce advantageous crops afterwards. It is in every one's power to estimate what the plowiug and seeding per acre of oat pasture with cost, and, according to circumstances, so will the expenses be, but in general where the expenses are high, the value of the pasture is equally so, and if even granted that the cost of plowing and seeding shall he double in value to the pasture produced let the comparative value of the field be fairly estimated before the course was begun—a waste or worn-out field—and what it is now, when the course is completed and laid down in clover, timothy, or orchard grass.

It will be of the first importance to have at least two fields, otherwise if the cattle are constantly upon the same field it will not be found so productive, and in wet weather they should be turued into soue field where the herbage was too hard in dry weather. It will be eaten greedily by the cattle after they have been satiated with the soft blades of the oats; under this management, beeves have been fatted for family use and taken off in December without any grain. It is observed that the oats scour at first, but the free use of salt readily corrects the complaint, and in no pasture do they rise faster in flesh, and the juices of their meat are uncommonly grateful.

The fields which have been in corn the preceding year have also been sown in the spring without being replowed, and have done equally well, except upon heavy clays, when the spring has commenced with heavy rains which have rendered the soil too compact to be opened, even with a heavy brake harrow, drawn by four horses. The fields from the oat pasture the foregoing autumu have also been sowu without replowing, when the spring has set in without much rain, after severe frost; not only the oat pasture but also the clover sown therewith have answered well.

Oats have also been sown among the hills and drills of corn after it has received the last dressing. It has succeeded, without any visible injury to the corn, provided care has been taken not to injure the roots by the plow or harrow at the time the oats were sown.

It has been inquired. Are not all crops of oats exhausting? If so, how can two sowiugs of oats in the same year render the soil fertile? It is granted if oats shall be matured into seed they will certainly exhaust, but if cut off while in the blade they and all culmiferous plants will fertilize. The experiment was made with Indian corn, sown broadcast, cut twice, and carried to the stable, and a crop of turnips taken off the ground the same season; the manure was laid on before the corn was sown, but none was given when the turnip seed was put in.

Another way in which oats fertilize appears to be from increase of vegetable soil. This is within the view of every observer. The remains of the pasture plowed in, particularly in July and August, is speedily decomposed, its tenderness and moisture aiding the dissolution. But dry stubble and husky roots are difficultly decomposed, nor do they produce so much carbonic or coally matter in the soil, which chemists say decomposes the water and produces the air required to promote vegetation. As the vegetable is produced from air and water, and not from earth, which seems to be no more than the laboratory where the process of vegetation commences, and fiually serves as a matrix to hold one part of the plant while the other parts are raised aloft in quest of superior aid to complete the inscrutable operations of the vegetable fabric.

It has also been inquired. Will this process of oat pasture fertilize everywhere? It is answered that where the soil and climate are the same the effects will be the same also. A description has been given of the soils where the experiments were made and are still going on. If experiments of the same nature shall be made upon a different soil and climate the result will be different, and more or less favorable, according to circumstances, and for which the practice now mentioned can not in justice be rendered accountable. If my shoe fits my foot I am warranted to say it will suit a foot of the same size and shape everywhere; let no one conclude that it will fit a foot of larger or less size or different form; but I must confess that passing over things equally obvious I have run into numerous aud expensive errors.

But when it is inquired upon what evidence it is to be received, the reply is at hand; living evidences are at the command of everyone who chooses to make the trial; let him, however, be on his guard against suffering himself to take a crop in place of the spring pasture oats.

If it shall still be inquired, How does the oat pasture fertilize? it may be also observed that the constant verdure and green herbage prevent the rays of the sun from parching the soil and depriviug it of its moisture and air, both of which are highly necessary to vegetation. The double portiou of juicy vegetable matter arising from the two crops of pasture in the same summer being everywhere united with the common soil, partly mechanically and partly chemically, renders the soil capable of retaining sufficient moisture and elastic air to make it open and warm, and by which the soil does not only become thicker by going downward, but actually expauds or rises so as to give a furrow, considerably deeper than formerly. over immovable rocks. Some years ago a field in view of the farmhouse marked the broad rocks during the course of every crop; they are now covered with so much soil that they are seldom observed. The two plowings also contribute to the increase of the air in the soil, without which no soil can be fruitful, there being no vegetation in vacuo. Tull's horse-hoeing husbandry was introduced under the idea that the pabulum of plants was pulverized earth. The fact daily before us is that pulverized earth retains the moisture and air as the handmaids of vegetation. Some experiments have lately been made the results of which favor these remarks, viz, "that soils afforded quantities of air by distillation somewhat correspond to the ratios of their values."

An article on the best method of reclaiming worn-out land was contributed by John Lang to the same society on December 12, 1810, and published in the second volume of the Memoirs, page 299, and following:

I conceive it a duty I owe the society to communicate through you the result of some experiments which I had set about for the purpose of ascertaining the best means of reclaiming old worn-out land. I had fondly listened to the method proposed by some, of improving with clover and plaster, without the use of lime, aud determined to try it. The field which I pitched upon for my experiments contains about 14 acres; it had been cleared about fifty-three or fifty-four years ago and continued in constant cultivation for upward of thirty years without manure of any kind. Some old people now living say that they have seen as good crops of wheat cut from it as ever they saw; but it was kept in cultivation till the produce would no longer pay for the labor, and has been thrown out a common for more than twenty years, till I fenced it in. I had the whole of the field plowed early in the spring of 1808. In the month of May one part of it was plowed again, and sown with buckwheat; this buckwheat was plowed in when in blossom and the land sown with buckwheat a second time, which was likewise plowed in and sowed with rye.

The other part of the field was limed at the rate of 25 bushels to the acre and planted with corn. The lime which I used was of the hot kind, from a quarry which is generally approved of for land in those parts; makes very strong mortar for building, but is not used for plastering, being granulated and not very white. I suppose it to be similar to that described by Doctor Darwin, which he supposes to have been primitive lime, broken down by the action of water and petrified a second time, which he thinks is the strongest lime.

The following summer was very dry, which, together with the heat of the lime, I supposed to be the cause why the corn became stunted and produced almost nothing. In the spring of 1809 the land was plowed and sowed with oats and clover; the other part of the field which was now in rye was likewise sowed with clover at the same time, and as soon as the clover began to appear above ground the whole field was sowed with plaster.

At harvest the oats was a very good crop, the rye was tall and well eared, but rather thin; perhaps it was owing to this circumstance that the clover among the rye looked better and more plentiful than that among the oats. I had not seen it until Wednesday the 4th instant, when I found that part of the field which had been limed closely covered with fine clover, whereas on that part which was not limed almost the whole of it had perished last winter, and what plants remained were weak and sickly, and abundance of wood grass beginning to appear, with which the field used to be almost covered while it lay a common; whereas not one plant of it is to be seen on that part which was limed. From this I concluded that if the system of improving with clover and plaster without lime should succeed in the end, it must be by a number of repetitions of the same process, which would require time and labor equal to if not exceeding the expense of lime, and the result uncertain. I therefore ordered that the part of the field which had not been previously limed should be limed as soon as possible, twice plowed, and sown with rye and clover next spring.

It was the opinion of the man who farms for me, as well as of others who made observations, that I missed it by planting corn with the lime; that if I had sown oats and clover the first spring, I would have had a profitable crop, besides gaining a year by my improvement, which was lost by the failure of the corn crop and part of the strength of the lime exhausted to no purpose. I am fully aware of the objection which some have to oats as an exhausting crop, and therefore ill calculated for advancing the improvement of worn-out lands. At the same time that I disapprove of the absurd practice of some farmers of sowing oats and buckwheat, year after year, as the worst of all rotations, I am convinced from long experience that an occasional crop of oats is no more exhausting than wheat, rye, or corn; that it is an excellent nurse for clover, a profitable crop for the farmer, and the straw good fodder or litter, without which he can not get much dung, the value of which is not sufficiently appreciated by many of our farmers. Every kind of grain which ripens its seed is an exhauster; even clover, which is the most ameliorating crop which we know, if it is but a moderate crop and left standing until its seed is full ripe, instead of improving, will be found to exhaust the land.

Before I conclude I must take some notice of the mild lime which I mentioned in a note at the bottom of page 8. I then supposed the mild lime above mentioned to be the property of Mr. Barnitt, of Marlborough Township, but when I was with my friend, Mr. John Mills, on the 4th instant, he told me that Mr. Barnitt's lime is the hottest and strongest lime in that neighborhood, that the lime which I alluded to is the property of Mr. Baker, of Newlin Township. The two limes are not more than 2 or at most 3 miles apart; Mr. Mills's farm lays nearly in the center between the two, and he occasionally uses both. He says that it requires 130 bushels of the mild lime to go as far on land as 100 bushels of the hot lime, that the mild lime is in its effects on land somewhat similar to that of dung, as it gives out its strength to the first crop, but in one or two crops more it is all gone; whereas, though the hot lime sometimes instead of helping rather injures the first crop, its good effects continue for many years. He showed me a clover field, one part of which had been manured with Mr. Barnitt's hot lime and the other with Mr. Baker's mild lime. I observed that wherever a heap of the hot lime had lain not a blade of vegetation of any kind had appeared, though Mr. Mills told me that every particle of it was shoveled off as clean as possible; but on that part of the field where the mild lime was put no such effects were produced. He told me further that the grain was best on that part where the mild lime was put, but the clover is greatly superior on the other part (it was all plastered alike), and I have no doubt that the succeeding crops will evince a decided preference in favor of the hot lime. I expect to procure specimens of both the above limes for the purpose of having them analyzed.

A very extensive examination of the use of gypsum as a fertilizer is also found in this volume. The article was prepared in 1797 and dedicated to George Washington, President of the United States, in the following language (page IX):

Sir: The following collection on the subject of the agricultural properties and uses of the gypsum, having been undertaken by me at your desire, I have thought there was a propriety in presenting it to you. However unimportant other parts may be, those which contain practical results I flatter myself will be useful.

I have had frequent occasions of knowing that the encouragement of agricultural improvement and information is among the favorite wishes of your heart. It is on this account and not with a design to give it an undue importance by placing it under your notice that I have been induced to inscribe to you this publication.

It is peculiarly consolatory when we can draw any portion of our comfort from our misfortunes. Your retirement from public life will afford you leisure and opportunities, by your patronage and example, to promote the interests of agriculture. Some compensation will thereby be afforded us for the loss we shall sustain by your resigning the helm at which you have so long, so wisely, and so safely steered our political barque.

Long may uninterrupted health, that first of blessings, enable you to enjoy the splendid evening of a life so much devoted to your country as to have been but little dedicated to yourself. And that you may be as happy as you have been eminently instrumental in making millions of your fellow-citizens is my sincere and ardent prayer.

I have the honor to be, with the most true and respectful esteem,

Your obedient servant,

Richard Peters.

January 3, 1797.

In the preface to this article is a strong argument for the establishment of a department of agriculture, page IX:

And yet the greatest improvements in husbandry have been either suggested or made by those who were not professional farmers. If pecuniary assistance should be required out of the public funds it should be afforded. A cent expended, with propriety, to aid and reward genius and industry in pursuing agricultural experiments and researches will add an eagle to the public stock. This is applying nourishment to the root of the public prosperity.

Were it without example it would be surprising that legislatures, consisting for the most part of farmers, have done so little for the encouragement of a profession which is calculated, above all others, to produce additions to the common mass of property by creating countless supplies drawn from the earth.

In England the establishment of a board of agriculture under the patronage and pecuniary encouragement of the legislature is recent, but its advantages are incalculable.

In France agriculture is accounted, as it really is in all countries, the basis of public and private wealth and prosperity. Its patronage and encouragement are placed among the first objects of public attention, and radically interwoven with the principles and system of their national policy and government. Perhaps the period is not distant when the public mind here will be turned to this subject. Nothing will then be wanting toward the accomplishment of every-destructive foes to the peace of a community and to the prosperity and happiness of individuals afflicted by a propensity to use them incontinently. Those who furnish the means of destruction are equally culpable with those who perish under their enticements.

An interesting book respecting the fertility of land is that written by Prof. Isaac Phillips Roberts, edited by L. H. Bailey, of Cornell University, entitled "The Fertility of the Land." In this work Professor Roberts takes up the problem of preserving and increasing the fertility of the soil. He defines the term "fertility" as commonly used in a special sense, meaning an abundance of nitrogen, phosphoric acid, and potash, but its true meaning is productive power. He states that land may contain any quantity of plant food in an inert state—that is, in a condition unsusceptible to plants, and yet, be sterile, whereas it may contain only a limited amount of plant food, and if that is available for the use of a plant it will be a fertile soil. He shows by analytical data that even poorer soils have an abundance of plant food, sufficient for several crops if it could all be utilized, while the richer soils in some cases have sufficient for two hundred or three hundred crops of wheat or maize. He says on page 19:

> This vast store of plant food is the farmer's stock in trade, the bank upon which he may draw. Its value can never be accurately determined, since a part of the plant food is not available, and since the power of the plant to secure that which is available depends upon many conditions, such as the correct preparation of the land, the kind of crops raised, the relative amounts of the various required constituents, and the amount of moisture present.

Again on page 32 he says:

> Since the soil and the subsoil contain such stores of potential fertility, and since tap-rooted leguminous plants bring to the surface abundant quantities of nitrogen with some mineral matter, and since many fields receive applications of farm manure from time to time, some far-reaching cause or causes must be present ever tending to seriously restrict production. It will be found that in this country the principal causes of low yields of farm crops are imperfect preparation of the land, poor tillage and hence a lack of available plant food, and insufficient moisture during some portion of the plant's life.

Professor Roberts in his book discusses the best method of tillage, the best means of preserving and applying manures, the best times of applying manures, the usefulness of nitrification, the home mixing of fertilizers, the value of lime, and many other problems connected with the conservation of soil fertility. I close this résumé of the history of soil fertility, its conservation and restoration by citing two classical works by American authors, well known and appreciated by all scientific agronomists, viz: Agriculture in Some of Its Relations to Chemistry, by F. H. Storer, and Soils, their Formation, Properties, Composition, and Relations to Climate and Plant Growth, by E. W. Hilgard.

A very remarkable document dealing with the fertility of the soil and its conservation is found in the annual oration delivered before the Chemical Society of Philadelphia on April 14, 1798. There are only a few copies of this document in existence. One of the most interesting of these is a copy given to Thomas Jefferson by the author himself, and now in the Library of Congress. On the title page is written in ink "To Thomas Jefferson, with the compliments of the author." The theme of the oration is a sketch of the revolutions in chemistry, by Thomas P. Smith, and it is dedicated to Robert Patterson, A. M., professor of mathematics in the University of Pennsylvania. At a meeting of the Chemical Society on April 14 the following resolution was adopted: "*Resolved*, That a copy of Mr. Smith's learned and ingenious oration be requested for publication. Extract from the minutes. George Lee, Jun. Sec'ry."

The concluding portion of this oration is as follows:

> The only true basis on which the independence of our country can rest are agriculture and manufactures. To the promotion of these nothing tends in a higher degree than chemistry. It is this science which teaches man how to correct the bad qualities of the land he cultivates by a proper application of the various species of manure, and it is by means of a knowledge of this science that he is enabled to pursue the metals through all the various forms they put on in the earth, separate them from substances which render them useless, and at length manufacture them into the various forms for use and ornament in which we see them. If such are the effects of chemistry, how much should the wish for its promotion be excited in the breast of every American! It is to a general diffusion of a knowledge of this science next to the virtue of our countrymen, that we are to look for the firm establishment of our independence. And may your endeavors, gentlemen, in this cause entitle you to the gratitude of your fellow-citizens.

DEFINITIONS OF SOIL FERTILITY.

The measure of the fertility of the soil is its ability under given seasonal conditions to produce a crop. The magnitude of the crop in those conditions affords a safe basis of judgment. It is true a crop does not get its whole nourishment from the soil. The carbohydrate matter, of which the largest part of every plant is composed, is taken from water and the carbon dioxid in the air or dissolved in the water. It is a self-evident axiom that the absence of any one essential element of plant food renders the production of a crop impossible. The absolutely essential substances necessary to plant growth are water, carbon dioxid, potash, and phosphoric and nitric acids. Essential elements are sulphur, lime and iron, magnesia and silica, and other mineral elements usually found in soils are also generally met with in plants, but are not deemed essential.

The soil plays a double rôle in plant growth—first it furnishes the physical support of the plant, and second it provides directly or intermediately the lime, potash, phosphorus, nitrogen, and sulphur, without which complete plant development is impossible.

The fertility of the soil is of two kinds, viz, temporary and continuing. Temporary fertility represents that excess of available plant food found in virgin soils and which rapidly disappears under continuous cultivation without fertilization. Temporary fertility also represents that increased power of production which a soil manifests under special tillage or by the application of manure and fertilizers. Continuing fertility is that which the soil maintains without the addition of fertilizing material and below which continual cropping can not reduce it. This properly represents the natural barrier interposed to prevent present agriculture from robbing future generations. It can not be doubted that if all the fertility of the soil could be put into enormous crops, say for a period of fifty years, the natural rapacity of man, from which even farmers are not free, would not be slow to utilize the gift. Future generations would be left to starve if nature permitted the enrichment of the present one. The phrase "continuing fertility" does not necessarily mean that there is no change in the degree of fertility or that there is any hard and fast line between it and temporary fertility. Experience has shown that in the great majority of cases a fertile virgin soil subjected to the usual practices in vogue in this country rapidly loses its fertility until a certain minimum production is reached. It then remains in this state with but little change for a long time. This fact has also been scientifically established by the celebrated experiments conducted at Rothamstead.

Now, if I understand the purpose of this discussion it is not how to preserve this minimum fertility but, on the other hand, how to preserve the higher fertility as shown in most virgin soils. On two previous occasions I have discussed this problem in detail, viz, in my address as chairman of Section C, of the American Association at the Buffalo meeting in 1886,[a] and the other in an address as retiring president of the American Chemical Society at Baltimore.[b]

In the address first mentioned I say: "The exportation of agricultural products becomes, therefore, a slow but certain method of securing soil exhaustion, and this accounts for the fact that countries, or those portions of countries which are devoted to almost exclusive agricultural pursuits, thus causing a continuous exportation of agricultural products, become the homes not of the richest but of the poorest communities."

It would be useless to deny in this connection that our own country, with a soil enriched by centuries of accumulating nitrogen, has grown rich from its agricultural exports. But when the last of our virgin soil shall have been placed under cultivation a continuous stream of such exports will certainly impoverish the nation and reduce all who practice such agriculture to the condition which has already been reached by those who have for years grown tobacco, corn, cotton, and wheat on the same soil and sold the products without paying back to the field the percentage of profits which was its due.

On the other hand, the farmer who is fortunate enough to be permitted to patronize the home market, who sells his maize and takes home a load of manure, adds not only to the plethora of his purse but also to the fertility of his soil.

Thus in the light of agricultural chemistry we see clearly the deep scientific basis of the teachings of political economy which show the value of the home market. While, therefore, the statement made at the commencement of this address, that the chief factor in the prosperity of a country is its agriculture, remains in every sense true, yet from the data discussed it as readily appears that agricultural prosperity is most intimately connected with the advancement of every other industry. Agricultural chemistry teaches the farmer to welcome the furnace and the mill, for in their proximity he secures a sure return to his fields of the plant foods removed in his crops.

We have seen by the foregoing discussion that, without any artificial additions, the soil, excluding the subsoil, contains enough of the two most important and valuable mineral constituents of plants to produce an average crop annually for 250 years. In point of fact, however, the impoverishment of the soil takes place at a much slower rate than this theory would indicate. It would, indeed,

[a] Proceedings of the Am. Assn. Adv. Sci., vol. 35.
[b] Journ. Am. Chem. Soc., Jan., 1894.

be a sorry thought to consider that in a quarter of a millennium the agricultural area of the earth would be incapable of producing further yields. Doubtless much of this reserve food is brought from the subsoil, and if it be possible for the subterraneous stores of these materials gradually to work their way surfacewards, even the remote future need not fear a dearth of them.

There is also a certain conservatism in crops, a vegetable "good breeding," which prevents the growing plant from taking all the food in sight. As long as there is abundance the plant is a hearty eater, but when the visible quantity of food falls to a certain minimum it remains for a long time without any rapid diminution. This fact is well illustrated in the experiments of Lawes and Gilbert at Rothamstead, where wheat was grown on the same unmanured field for forty years in succession.

In the "Summary and general conclusions" derived from these experiments, these celebrated agronomists say: "A soil which in the ordinary course of agriculture would have received an application of manure before another crop was sown, has produced crops of wheat in succession, averaging 14 bushels per acre, solely by means of its existing fertility. * * * The stock of potash and phosphoric acid has been largely reduced. Although so much soil fertility has been removed, the stock that remains would appear to be sufficient to grow crops of wheat for a very long period; the produce, however, must, in process of time, necessarily be lower than it has hitherto been."

THE ROTATION OF CROPS.

The great utility of a proper rotation of crops in conserving the magnitude of the yield is one of the best known principles in scientific agriculture. Various and ingenious theories have been presented to account for this benefit. In this connection it seems to me desirable to point out the true cause of the benefit derived from the rotation of crops. There is nothing mysterious or occult in plant growth. As in the case of animals, plant growth consists in pure chemical transformations. There is no such thing as "vital principle" or "mysterious force," or "supernatural influence." Every operation is based upon the principles of chemistry. The course of the sap in the plant, the nourishment of the germ, the transformation of the carbon dioxid of the air, the building of inorganic into organic products, the building up and decomposition of plant materials are all governed by the laws of chemical science.

Attention has already been called to the fact that the sources of plant food are so distributed in nature that they become available little by little, thus securing for future generations the possibility of life which would be speedily denied them if soil fertility could be utilized within a few years. The well-known principle of the law of the minimum, it seems to me, is the true explanation of the benefit of crop rotation. If all crops used their foods in the same proportion, there could be little benefit derived from crop rotation, but as in the case of animals so it is with plants. Some animals live exclusively on flesh foods; others live exclusively on vegetable foods; others on mixtures of these foods in varying proportions. It is evident that if all animals lived on flesh foods starvation would soon take place. It is evident, further, that if all animals lived on vegetable foods the food problem would be immensely increased in difficulty, and if all animals lived on the same proportions of vegetable and animal foods there would be a stringency in some quarters due to the exhaustion of one or another of the principles of the foods. The same law holds good with the plant. While all plants live on essentially the same kinds of food, the quantities of any particular kind required vary in every plant. It is only necessary to study the life history of any one plant and compare it with the life history of another to show this fact. For instance, a study of the nutrition of wheat as compared with the nutrition of the sugar beet will indicate in probably an extreme manner the variations of the proportions of the various plant foods required. Hence if a crop, such as the sugar beet, is grown continuously on a field without the administration of any artificial food, the particular character of the plant food furnished by the soil which is most required is soon reduced to a minimum of production, while at the same time other varieties of plant food may still exist in abundant proportions. In this condition the sugar beet grows only with its minimum crop. If any cereal, such as wheat, be planted in the same field, all the elements necessary to the production of wheat may still be present in abundance and the maximum crop of wheat will be produced. Since plant foods are furnished constantly in soils chiefly by progressive decomposition and by capillary translation, the best results are necessarily secured by changing crops. This principle will account for the principal benefit secured by crop rotation. There are of course other factors, such as character of the cultivation, the variations of the bacterial flora, the increasing or decreasing acidity, which play a prominent but not a dominant rôle. But in each of these cases the general law of supply and the general law of the minimum hold good.

LOSSES DUE TO INSECTS.

PART I. INSECTS AS A CHECK ON AGRICULTURAL PRODUCTION AND AS A SOURCE OF WASTE TO ACCUMULATED SUPPLIES.

By C. L. Marlatt,
Bureau of Entomology, U. S. Department of Agriculture.

INTRODUCTION.

The value of the farm products of the United States for the year 1907 is estimated by the Secretary of the United States Department of Agriculture at $7,412,000,000 at the point of production. Of this total $4,742,000,000 are plant products. The accumulated stores of previous years of such staples as the grains, tobacco, etc., will easily bring the value of plant products of this year, subject to loss from insects, to upward of $6,000,000,000. To one familiar with the work of important insect pests on farm crops, stored grains, and other stored products entering into this total, it is not difficult to approximate the probable shrinkage due to insects. The detailed description of such shrinkage which follows indicates that it will rarely fall below 10 per cent of the total value, and in the case of certain important farm staples may, in years of excessive damage, amount to 50 per cent. For the cereal grains and other important field crops a minimum 10 per cent rate of loss from insects has been adhered to. The rate of loss, however, is much heavier with certain other classes of farm products, such as truck crops and fruits, being certainly not less than 20 per cent for the former and 30 per cent for the latter. As will be indicated more exactly farther on, this resulted for the year 1907 in a shrinkage in value of all plant products of the farm of $552,500,000. To this must be added the injury occasioned by insect pests to farm products in storage, amounting to at least $100,000,000, making a total tax in 1907 of $652,500,000 on the plant products of the farm chargeable to insects, and this is approximately the annual tax which insects impose on such products in the United States. That this estimate, which at first may seem absolutely preposterous, has really a reasonable basis will be indicated, it is believed, by the more detailed consideration of the nature of the losses which follows.

BASIS OF ESTIMATES.

The estimate of losses is based on the farm price of the crop actually harvested, and does not, therefore, take into account the possible reduction in value which would follow the marketing of the larger crop. While it is true that prices are regulated by production, the factor of distribution, especially in the case of cereals, often predominates, so that large crops may bring good prices and small crops low prices. During the last fifteen years, for example, the price of wheat in this country has exhibited little if any relation to our own production. The bumper wheat crop of 1901 of nearly 750,000,000 bushels brought to the farmer 23 cents a bushel more than the crop of 1894, which was 300,000,000 bushels less, or but little more than half the production of 1901; and for several years the farmer has been getting higher prices for wheat on crops larger than the average.

Some definite means of estimating losses must be assumed, and any effort to scale down these losses by reckoning possible enhancement of the market price, in view of the conditions just cited, would come more in the category of pure guesswork and be open to quite as great objection as the plan adopted. As an offset to possibly enhanced values due to shrinkages occasioned by insects, moreover, are certain very legitimate items of cost. A very considerable item of loss properly chargeable to insects is the annual expenditure devoted to their control, which, except in the case of certain fruit and truck crops, has not been considered in the estimates. This amounts to a large percentage of the value of the crop in the case of orchard fruits, truck crops, and of such field crops as cotton and tobacco. In the case of the cereals, protection is chiefly secured by farm practices, such as rotation of crops, variations in the time of planting, etc., and this also applies, to some extent, to cotton, tobacco, and truck crops. In estimating the losses due to the codling moth, for illustration, it is shown that a sum of $5,000,000 a year is expended in spraying apple trees, allowing a cost of only 10 cents per tree for one-fourth of the bearing trees. In the case of citrus fruits the cost of gassing and spraying ranges from 10 cents to $1.50 per tree.

Another legitimate class of losses not included in the estimate is the secondary losses which necessarily result from diminished products. For example, the excessive reduction in winter wheat through the Hessian fly ravages in 1900 put a serious check upon milling operations throughout the region worst affected and caused very heavy loss in this field of industry. Similarly a shortage of cotton may so increase the values as to lead to the shutting down of cotton mills, as has been illustrated recently. A shortage of grains means a corresponding loss to railroads and other transportation companies and to shippers. In other words, any material shrinkage in an important product starts a train of losses to the end of the chapter, the total amount of which is quite beyond calculation or estimate.

The writer believes that these omitted items of loss will make good any difference of price which might result from the larger crops if insect damage were entirely eliminated.

Irrespective of the monetary consideration is the actual material loss in products, which is absolute so far as the consumer is concerned. From the standpoint of the producer, also, the action of injurious insects is to put a check on production, and the shrinkage of crops represents wasted effort. In other words, were it not for these pests, a lessened acreage and a saving in labor would produce an equivalent crop.

A general view of the relation of insect losses to the important staples is given in the table below. The value of plant products is based on the report of the Secretary of the United States Department of Agriculture for 1907. The last two columns, indicating the shrinkage due to insect work, are based on the crop actually harvested; that is to say, except for such damage the crop would have been 10 or 20 per cent greater.

Values of plant products for 1907 and losses chargeable to insect pests.

Product.	Value.	Percentage of loss.	Amount of loss.
Cereals	$2,378,000,000	10	$237,800,000
Hay	660,000,000	10	66,000,000
Cotton	675,000,000	10	67,500,000
Tobacco	69,000,000	10	6,900,000
Truck crops	[a] 340,000,000	20	68,000,000
Sugars	64,000,000	10	6,400,000
Fruits	[a] 220,000,000	30	66,000,000
Farm forests	[a] 150,000,000	10	15,000,000
Miscellaneous crops	[a] 189,000,000	10	18,900,000
Products in storage			100,000,000
Total	4,745,000,000		652,500,000

[a] Estimate only.

An explanation of the nature of the loss and method of computation for the different products as above classified follows:

INSECT DAMAGE TO CEREAL CROPS.

Only the losses to the two most important cereals, corn and wheat, will be discussed in this paper, as the injury to oats, barley, rye, etc., will average about the same percentage and need not be specifically analyzed.

INSECT DAMAGE TO CORN.

In point of quantity and value, corn is the leading cereal crop of the United States. Its annual farm value in later years has been upward of $1,000,000,000. While less subject to insect damage than wheat, the next most important cereal, the corn product would be considerably greater were it not for important insect pests. The work of several of these is obscure, and many farmers are entirely ignorant even of the existence of some of the worst enemies of this crop. In this last category falls the work of the corn root worm (*Diabrotica longicornis*), which ordinarily passes unnoticed, or at least is often misunderstood. The larva of this insect feeds on the roots of young corn, and in regions of bad attack may cause almost an entire loss of the stand. The corn root worm, together with one or two allied species working in substantially the same way, causes an annual loss of at least 2 per cent of the crop, or some $20,000,000.

Perhaps the next most important insect pest of this cereal is the bollworm or earworm. This insect, as shown by Mr. A. L. Quaintance, of this bureau, probably attacks from 90 to 100 per cent of the ears of sweet corn throughout the country, and in the South practically an equal percentage of the ears of field corn, as shown by actual counts in the field made during the years 1902 and 1903. The average loss in the number of kernels to an attacked ear is 15 per cent, or, if allowance be made for the smaller size of the terminal kernels, at least a loss of 7½ per cent. The percentage of loss is less in the great corn areas of the Northern and Middle States, but a 2 per cent loss for the United States chargeable to this insect is certainly well within the limits of actual damage, and would, for the corn crop of 1904, indicate a loss of over $20,000,000.

Of perhaps equal importance to this crop are the depredations of the chinch bug. Chinch-bug injury is, as a rule, more marked where corn is grown in the neighborhood of wheat or small grains, and in such cases the migration of the chinch bug from wheat to corn may often result in the total destruction of considerable areas of corn. The chinch bug is a strong flier also, and at the period of migration in midsummer corn is often attacked, the loss in the case of this cereal being, however, very much less than in the case of wheat. For the country as a whole, however, the loss from the chinch bug, taking one year with another, will probably be 2 per cent of the crop, or, estimating from the crop of 1904, $20,000,000.

Every year in different sections of the country there is notable injury to corn by such insects as billbugs, the various wireworms, cutworms, army worms, stalk borers, various species of locusts or grasshoppers, corn plant lice, and others, to a total of fifty fairly important species. These minor pests undoubtedly cause a loss of an additional 2 per cent, making a total annual injury of 8 per cent and indicating a loss of $80,000,000.

INSECT DAMAGE TO WHEAT.

Of the cereal crops of this country wheat suffers most from insect depredations. Of the large number of insects which depredate on this cereal, the three important species are the Hessian fly, the chinch bug, and the grain plant louse, using the latter term to include several allied species which work in much the same manner.

The chinch bug is notably a wheat pest, although its damage to other cereals and forage crops is very considerable. The losses from the depredations of this insect on wheat in single States have ranged between $10,000,000 and $20,000,000 in one year. A very reasonable average annual estimate of loss, taking the country as a whole, would be 5 per cent of the value of the wheat crop, which would indicate about $20,000,000 a year chargeable to this insect.

The Hessian fly is distinctly a wheat pest, although doing some damage also to rye and barley. The losses due to it will be considered in detail to indicate their nature specifically and to illustrate the exactness and reliability which may sometimes characterize records of this kind relating to particular pests of a single crop.

The season of 1900 is notable in Hessian-fly annals as exhibiting the most destructive work of this pest in recent years. The fly was very generally present throughout the main wheat-growing districts of the Ohio and Mississippi valleys, but its ravages were that year concentrated particularly in Ohio and Indiana. The statistics of the acreage and yield of wheat and the value of the crop for that year for the States mentioned reflect very plainly the loss occasioned by this pest. The wheat area in these two States in 1900 and the years immediately preceding was about 5,000,000 acres. Chiefly on account of the ravages of the Hessian fly more than half of this acreage (2,577,000 acres) had been abandoned and planted in other crops prior to May 1, 1900, as shown by the records collected by the Bureau of Statistics of this department. The abandonment was about 40 per cent for Ohio and 60 per cent for Indiana. The cost of the preparation of soil, planting, and seed wheat for this abandoned acreage is all that need be reckoned, inasmuch as it was possible to use the land for other crops, such as corn or oats. The loss in labor and material indicated will approximate $3.50 per acre, giving a total of over $9,000,000. Of the remaining wheat acreage, the average yield per acre for this year in Ohio was 6 bushels, as against 15.3 bushels for the year following, 14.2 bushels for the year previous, and nearly 17 bushels for the years 1897 and 1898. For Indiana, the yield per acre in 1900 was only 5.3 bushels, as contrasted with 15.8 bushels for 1901, and 15.6 and 9.8 bushels, respectively, for 1898 and 1899. In other words, a decrease of nearly two-thirds in the yield per acre is shown for these two States for the area in wheat which was left for harvesting. The Hessian fly does more or less damage every year, which reduces the average yield per acre, and, therefore, if such damage be eliminated the average yield per acre should be in the neighborhood of 15 bushels, indicating a loss for that year of nearly 10 bushels per acre for the area harvested, or, for the two States, of 24,230,000 bushels of wheat, of approximately a farm value (at the low price for that year) of $15,000,000. This loss, combined with the $9,000,000 indicated for abandoned acreage, gives a total direct loss for Ohio and Indiana of over $24,000,000. These figures, enormous as they are, are based on the careful statistical records of the acreage, yield, and prices of 1900 collected by the statistician of the department, working entirely independently of the Bureau of Entomology.

During this year the damage in other wheat-producing States was notable. For example, more than 20 per cent of the planted area of Michigan was abandoned, and lesser amounts in other States, with great shrinkage in the yield which was actually harvested. The loss, therefore, for this single season due to the Hessian fly undoubtedly approached $100,000,000.

The losses occasioned by this insect, while showing great fluctuation, as indicated, are an annual tax on the wheat crop. Except in cases of exceptional severity they pass, however, comparatively unnoticed. For example, the Hessian fly was not especially complained of in 1904, yet the agent investigating the insect enemies of cereal crops in the Ohio Valley reported that many fields showed injury to the extent of from 50 to 75 per cent. In comparatively few years this insect causes a loss less than 10 per cent of the crop, or the equivalent of a shrinkage of over 50,000,000 bushels in the yield, or, on the valuation of the crop for 1904, of over $40,000,000.

The losses due to grain plant lice are often very heavy, as may be illustrated by the extraordinary invasion of the so-called green bug in Texas and Oklahoma in the season of 1907. Statistics of these two States only are given, but the green bug spread its damage extensively into Kansas and was the occasion of more or less loss to small grains throughout the United States east of the Rocky Mountains. In Texas and Oklahoma, however, the damage was excessive, and over vast areas the wheat and oat crop was totally destroyed. The shortage of these crops in these States is to be attributed practically to this one source, as the conditions were otherwise favorable for an average yield. As shown by the records of the Bureau of Statistics of this Department, there was a reduction of over 24,000,000 bushels in yield of wheat over the preceding year (1906) from a similar acreage planted for Texas and Oklahoma, and a shrinkage of more than 35,000,000 bushels of oats. The grain thus lost represents an approximate farm value of $32,000,000. Some of this loss was made good by the replanting of the ravaged fields in other crops, but the cost of the preparation of the soil for planting and the seed grain for the abandoned acreage (nearly three-fourths of the area planted), and the very much lessened yield of the acreage actually harvested, makes a large percentage of this amount an actual loss. The plant louse occurs every year throughout the Mississippi Valley and eastward, always inflicting more or less damage, and with a favorable season may any year cause a loss similar to that witnessed in Texas and Oklahoma in 1907. The average annual loss from this and other plant lice certainly amounts to 2 or 3 per cent of the wheat crop.

The many other insects depredating on wheat, including grasshoppers, the wheat midge, several species of sawflies, and the cutworms and army worms, will swell the total of loss to at least 20 per cent of the crop. In other words, were it not for the attack of these pests the wheat crop would be one-fifth greater than it now is, or would have an additional value of approximately $100,000,000.

The insect damage to other cereal crops probably falls short of 10 per cent. A 10 per cent average, however, for all the cereals is certainly a reasonable one and is the basis of the loss indicated in the general table.

INSECT DAMAGE TO HAY AND FORAGE CROPS.

The damage by destructive insects to hay and forage crops is more obscure and less generally understood than in the case of any other farm products. Certain of the larger insects depredating on hay and forage crops are commonly known. These include the various species of locusts or grasshoppers, army worms, and cutworms. Very little understood and generally overlooked, however, are the webworms and small grass worms (*Crambus* spp.) which work about the base or roots of the plants, and which are so abundant that at certain seasons the moths flit up in front of one at every step. Swarming also in grass lands are many species of minute leaf hoppers which reduce the yield enormously, their small size being more than offset by their prevalence and numbers. Obscure, but very important also, are the white grubs which work on the roots and often kill the grass outright over large areas, and everywhere tax production heavily. In the same class in habit are the meadow worms or leather jackets, the grass-root feeding larvæ of the crane flies. A 10 per cent shrinkage from these and other pests in grasses and forage plants is a minimum estimate.

INSECT DAMAGE TO COTTON.

The principal insect depredators on cotton are the cotton-boll weevil, the bollworm, and the leaf worm. Many other insects, however, inflict minor damage. The loss chargeable to the boll weevil, from the very conservative estimate of Mr. W. D. Hunter, the agent charged with the study of this insect in Texas, represents, for the year 1907, some $25,000,000.

The bollworm is chiefly destructive in the southwestern cotton-producing States of Mississippi, Oklahoma, Arkansas, Louisiana, and Texas, causing a damage of from 2 to 60 per cent of the crop; it has been very conservatively estimated by Mr. A. L. Quaintance at 4 per cent of the crop and indicates an annual loss of some $12,000,000. East of these States comparatively little damage is done by the bollworm.

The cotton-leaf worm in years of excessive damage, before arsenical poisoning was a common practice, caused a loss of $20,000,000 to $30,000,000. The present damage is very much reduced, but with the increased acreage of cotton an annual loss of from $5,000,000 to $10,000,000 may be conservatively estimated.

Without counting the losses due to a host of minor insect depredators, we have already a total annual loss of more than $40,000,000 chargeable to three important insect pests of this staple.

INSECT DAMAGE TO TOBACCO, TRUCK CROPS, SUGAR CANE, ETC.

Detailed statements relative to insect losses to the crops enumerated above will not be attempted in the space at command. All are subject to attacks of important insect pests, and a reasonable estimate of the annual damage is 10 per cent of the value of the first and last named crops, and fully 20 per cent in the case of truck crops. Vegetables and other truck crops are especially subject to insect injury; furthermore, there is always a large expenditure in the control of insects, the items of which and of actual damage together probably making the tax due to insects double the normal 10 per cent rate.

INSECT DAMAGE TO MISCELLANEOUS CROPS.

A great many minor crops enumerated in the census of 1900 can not be discussed separately; consequently, the valuation of the crops is lumped together and a 10 per cent loss chargeable to insects estimated on the whole, which seems reasonable in view of the examinations already made of the more important farm products.

INSECT DAMAGE TO STORED PRODUCTS.

The estimates given in the foregoing discussions relating to vegetable products give the shrinkage due to attacks of insects to growing and maturing crops. After these crops have run the gauntlet of insect enemies during their entire period of growth, notably the cereal and forage crops, tobacco, and certain truck crops, they are still subject to the inroads of another class of insect depredators while in storage on the farm, or, in greater accumulations, in elevators and mills, or, again, while in transit, especially in the case of long shipments by sea. The cereals are kept in storage until consumed, which means a considerable period for the bulk of the crop. The various grain weevils and beetles, flour moths, and other insect pests which depredate on stored grains frequently cause great losses, and an estimated injury of 5 per cent is a reasonable and probably minimum figure. Computing this percentage, therefore, on the valuation of the cereal products for 1907 we have an annual loss of more than $100,000,000.

The location of food products for human consumption is in the house storeroom and kitchen, and often this last opportunity for insect damage is improved by various species of the stored-grain pests already referred to. Animal products are attacked by larder beetles, ham beetles, etc.; fruits by various fruit and vinegar flies; and woolens or household furnishings by carpet beetles, clothes moths, silver fish, etc.

Cured tobacco is especially subject to insect attack and damage, the most important source of injury being a minute insect known as the cigarette beetle, which not only eats into cigarettes but into all other forms of cured tobacco. It is now widespread in America, occuring in practically all factories, warehouses, and retail establishments, and is frequently the cause of very heavy losses.

In the general table a total loss of $100,000,000 is indicated for insects attacking stored products. This is covered by the loss for cereal products alone, and if the other items of loss just enumerated were included a considerable increase in the estimate could legitimately be made.

CONTROL OF INJURIOUS INSECTS.

The enormous annual loss which may now be fairly charged to insect pests can be very much limited by the more general adoption of known methods of control and by thoroughgoing investigations to discover other practicable means of prevention. In no country in the world has the problem of insect control been more energetically taken up than in the United States, both in the work of the Bureau of Entomology of the United States Department of Agriculture and of the state and experiment station entomologists of the various States. The methods of controlling important insect pests which have resulted from the studies of the last twenty-five years, and which have been adopted by the more progressive farmers and fruit growers, have already put a large limitation on insect losses. As a general proposition, fruit growing in this country would practically come to an end if sprays and other means of control, which have resulted from the studies of the problem by experts, were discontinued, and a vast increase in the losses to cereals and other crops and to animal products would result from neglect of known measures applying in these fields.

As illustrating the saving from insect losses now effected and pointing to still greater ones, which will come as a result of future work and the more general adoption of known methods, a few common examples may be given. The cotton worm, before it was studied and the method of controlling it by the use of arsenicals was made common knowledge, levied in bad years a tax of $30,000,000 on the cotton crop. The prevention of loss from the Hessian fly, due to the knowledge of proper seasons for planting wheat, and other direct and cultural methods, results in the saving of from $100,000,000 to $200,000,000 annually. Careful statistics show that the damage from the codling moth to the apple is limited two-thirds by the adoption of arsenical sprays, banding, and other methods of control, representing a saving of from $15,000,000 to $20,000,000.

The existence and progress of the citrus industry of California were made possible by the introduction from Australia of a natural enemy of the white scale, an insect pest which was rapidly destroying the orange and lemon orchards, this introduction representing a saving to the people of that State of many million dollars every year. The rotation of corn with oats or other crops saves the corn crop from the attacks of the root worm to the extent of perhaps $100,000,000 annually in the chief corn-producing regions of the Mississippi Valley. The cultural system of controlling the boll weevil is already saving the farmers of Texas many millions of dollars, and, in fact, making the continuance of cotton growing possible, and scores of similar illustrations could be cited.

PART II. INSECT DAMAGE TO FRUITS.

By A. L. Quaintance,
Bureau of Entomology, U. S. Department of Agriculture.

INTRODUCTION.

As indicated in an introductory paragraph in Part I, the insect injury to orchard and small fruit is exceptionally heavy, and in spite of the corrective measures there is a tax of at least 30 per cent on production. Remedial measures are of the greatest importance in this field, and were it not for the insecticide and other treatment now practiced the commercial fruit interests of this country would be practically annihilated. In addition to the horde of native species which have in great measure left their native wild food plants and attack orchard products, many of the most serious fruit insect enemies of the Old World have been introduced into this country, often without their natural checks, for which and other reasons they have here become excessively injurious. The control of most orchard insects takes the form of spraying, and while this is relatively very expensive, fruit spraying yields a larger percentage of benefit than is the case with many other crops.

The detailed examination of the subject which follows covers the leading insect enemies of the principal deciduous fruits, such as the codling moth, San Jose scale, peach-tree borers, grape phylloxera, etc. The citrus and subtropical fruits have not been specifically considered, but with these the rate of loss, together with the cost of protective treatment, is fully as heavy as with the deciduous fruits. A total insect tax on deciduous fruits of more than $66,000,000 is indicated, and this is really a moderate estimate, as will be seen from the discussion of the several items entering into this total. The cost put down for spraying trees and the losses to fruit are minimum charges, and are very generally exceeded in actual orchard practice and experience.

THE CODLING MOTH.

The codling moth has been depredating on the American apple crop for upward of one hundred years, and during this period has destroyed fruits to the value of several hundred millions of dollars. Within the past twenty years a very large sum has been expended in its control.

The average annual apple crop from 1897 to 1907, as shown by statistics obtained by the American Agriculturist, is approximately 37,000,000 barrels. Assuming that there is a 25 per cent loss of fruit from this species, the figures of yield given represent three-fourths of the total crop—that is, the shrinkage in yield is about 12,330,000 barrels, which, with a valuation of $1.25 per barrel, represents about $15,500,000. Deducting from this amount the possible value of the fruit for cider, vinegar, etc., at 30 cents per barrel, there is a net loss of $11,750,000.

Assuming that but one-fourth of the total number of apple trees are sprayed each year, and at a cost of 10 cents per tree, the cost of treatment is about $5,000,000.

The total annual tax of this species to the apple growers of the United States thus amounts to about $16,750,000, as explained more in detail below:

DAMAGES BY THE CODLING MOTH.

(*Carpocapsa pomonella.*)

In estimating the annual loss from this insect to apple crop, the American Agriculturist figures of crop were used, and the average crop of the past ten years was taken as a basis:

Average crop, 1897 to 1907, inclusive (barrels)	37,000,000
Estimated that only one-half of total number of trees are in bearing any one year (off year, cold, etc.), crop from, approximately (trees)	100,000,000
Estimated that only one-half of this number of trees are sprayed	50,000,000
Estimated that in unsprayed orchards there is a loss each year of 50 per cent of crop.	
Shrinkage in yield, 25 per cent of whole crop, or 50 per cent of crop on the 50,000,000 unsprayed trees (one-third of 37,000,000 barrels)	12,333,333
Value of shrinkage, at $1.25 per barrel	$15,416,666
(Average price per barrel for past ten years at principal eastern markets was $2.65.)	
Less value of culls, at 30 cents per barrel	3,699,999
Net loss on crop	11,716,667
At 10 cents per tree, cost of spraying 50,000,000 trees	5,000,000
Present loss and cost of treatment	16,716,667

THE SAN JOSE SCALE.

The outlay necessary to bring an orchard to bearing age is considerable, amounting under favorable conditions of management to from 50 cents to $1 per tree. The destruction of trees by scale or other causes before fruiting begins, or later, represents therefore a loss of invested capital aside from the loss of possible dividends from the fruit produced. Losses from the San Jose scale have been occasioned largely by the wiping out of capital invested in orchards by the destruction of the trees. Since its introduction into California in the early seventies, and its appearance in the East some fifteen years later, losses of this character to orchards and other plants have been perhaps not less than fifty or sixty million dollars.

A conservative estimate of its injuries at the present time indicates that of the 350,000,000 trees of the more important deciduous fruits, as given in the 1900 census, about 80,500,000 are infested. It is believed that three-fourths of this number, or 60,000,000, are now being treated, resulting in the preservation of trees worth at least $46,000,000.

The annual loss resulting from failure to spray amounts on the same basis to about $5,000,000. The cost of treating the 60,000,000 trees, at 9 cents each, is about $5,500,000, aggregating a total annual charge against this species of $10,500,000, as detailed below.

DAMAGES BY THE SAN JOSE SCALE.

(*Aspidiotus perniciosus.*)

The number of trees subject to infestation as given by the 1900 census was taken as a basis. The number of trees infested was determined by estimating the percentage of infestation in the various States where the scale is known to occur.

Apple trees infested	40,383,339	Now sprayed	30,287,505
Peach and nectarine	27,911,032	Do	20,933,274
Pear trees infested	3,116,884	Do	2,337,663
Plum and prune infested	9,014,316	Do	6,760,737
Total	80,425,571	Total	60,319,179

Value of orchard interest now saved by spraying:	
30,297,505 apple, at $1 per tree	$30,279,505
20,933,274 peach and nectarine, at 50 cents	10,466,637
2,337,633 pear, at 75 cents	1,753,224
6,760,737 plum and prune, at 50 cents	3,380,368
	45,879,734
Loss from San Jose scale:	
One-fourth of infested apple trees, not sprayed, 10,095,834, at $1 each	10,095,834
One-fourth of infested peach and nectarine trees, not sprayed, 6,997,758, at 50 cents	3,488,879
One-fourth of infested pear trees, not sprayed, 779,221, at 75 cents each	584,415
One-fourth of infested plum and prune trees, not sprayed, 2,253,579, at 50 cents each	1,126,798
	15,295,917
Assuming that only one-third of these trees die each year, annual loss becomes	5,098,639
Cost of treatment, 60,319,179 trees, at 9 cents each	5,429,626
Total annual loss of trees and cost of treatment	10,528,265

PEACH TREE BORERS.

Throughout its area of culture the peach is subject to attack from *Lepidopterous larvæ*, which feed on the inner bark, at the base of the tree, on the roots, or along the trunk. Young trees are especially injured and often killed, and older trees are often so weakened that normal crops are not produced. Using the 1900 census figures as a basis, at a valuation of 50 cents per tree and an estimated injury of 10 per cent, the losses from this species become $5,000,000.

There is also a large expenditure in labor in worming trees (the method principally relied upon to control the species), amounting perhaps to at least $1,000,000, making a total charge against this species of $6,000,000.

DAMAGES BY PEACH TREE BORERS.

(*Sanninoidea exitiosa; S. opalescens; Synanthedon pictipes.*)

The number of trees as given by the 1900 census was taken as a basis.

Number of peach and nectarine trees approximately	100,000,000
Value, at 50 cents per tree	$50,000,000
Estimated an annual shrinkage in value of 10 per cent	$5,000,000
Estimated cost of treatment, mostly digging out	1,000,000
Total	$6,000,000

GRAPE INSECTS.

The grape suffers severely from insect attack. The *Phylloxera* in California, to which State its injuries are principally confined, causes an estimated annual deterioration in condition of vineyards of not less than 5 per cent. On this basis its injuries represent a loss of about $3,500,000.

The grape root worm for some years has threatened the grape industry in the Erie and Chautauqua grape belts in New York and Pennsylvania, and has done a large amount of damage in Ohio. Considering its injuries in this territory only, an estimated annual deterioration in the condition of vineyards of 10 per cent results in the loss of something more than $1,750,000. If to this be added all expenditures for treatment, there is a total of over $2,000,000 which this species taxes the grape growers of this limited territory.

The grape leaf hopper, another important enemy of the vine, occurs all over the United States, and is present in vineyards every year, in many instances being excessively destructive. At the low estimate of injury of 2.5 per cent for the United States as a whole, the deterioration in condition of vines resulting from the attack of this species is about $2,250,000. There are numerous other grape pests that locally often become seriously destructive, as the rose bug, grape berry moth, flea beetle, leaf caterpillars, etc. The total loss from these several pests of $1,000,000 each year, including money spent in their control, will be quite conservative. The annual loss throughout the country to vineyards therefore is about $8,750,000.

DAMAGES BY GRAPE INSECTS.

[Figures of 1900 census were taken as a basis.]

Phylloxera.

Number of vines in California	90,686,458	
Value, at 75 cents per vine	$68,014,843	
Estimated 5 per cent annual shrinkage in value of vineyards from *phylloxera* attack		$3,400,742

GRAPE ROOT WORM (*Fidia viticida*).

Number of vines in Pennsylvania, Ohio, and New York (principal area now seriously injured)	37, 801, 289	
Value, at 50 cents per vine	$18, 900, 644	
Estimated 10 per cent reduction in value		$1, 890, 000
Cost of treatment		200, 000

GRAPE LEAF HOPPER (*Typhlocyba comes*).

Total number vines in the United States	182, 333, 064	
Value, at 50 cents per vine	$91, 166, 532	
Estimated 2½ per cent reduction in value		$2, 279, 163
Practically no treatment is given.		

MISCELLANEOUS GRAPE INSECTS (ROSE BUG. BERRY MOTH, CATERPILLARS, ETC.).

Estimated annual injury, and cost of treatment for these several species	$1, 000, 000
Total for grape insects	8, 769, 905

THE PLUM CURCULIO.

The plum curculio is a native species and from earliest times has depredated upon stone fruits, and during the past fifteen or twenty years its injuries have become very important. This insect is confined to America so far as is known, and in the United States does not occur west of about the one hundredth meridian. Taking into account its distribution and its injuries to the apple crop in the Middle West and eastern States, on the basis of a 10 per cent reduction in yield, there results a loss of about $3,250,000. Assuming a loss to the peach crop of 33 per cent, the injuries to peaches, including the cost of remedial work, brings about a loss of somewhat more than $4,000,000. On the basis of a 50 per cent reduction in yield of plums and prunes throughout the infested territory, including the cost of treatments, there is a loss of about $1,250,000.

The total annual loss to its several food plants amounts to about $8,500,000.

DAMAGES BY PLUM CURCULIO.

(*Conotrachelus nenuphar.*)

APPLE.

[The figures for the apple crop in the following estimate were furnished by the American Agriculturalist.]

Average crop, 1897 to 1907, in the infested territory (barrels)	34, 292, 700
Estimated shrinkage of first-class fruit, 10 per cent	3, 429, 270
Value, at $1.25 per barrel	$4, 286, 587
Value of fruit as culls, at 30 cents per barrel	1, 028, 781
Total	$3, 257, 806

On apples this insect receives but little if any treatment aside from that given in codling-moth treatments.

PEACH.

There are no available figures on the yield of peaches. It was thus necessary to determine this as accurately as possible on the basis of the number of trees and a conservative yield which each should give.

Number of trees in infested territory	90, 931, 542
Assuming that one-fourth bear every year, producing an average of 1 crate per tree, valued at 50 cents, net value	$11, 366, 443
Estimated annual loss of 33 per cent	$3, 788, 814
Cost of spraying, jarring, etc	300, 000
Total	$4, 088, 814

PLUM, PRUNE, ETC.

There are likewise no figures on the yield of the plum, prune, etc., and the yields of these fruits were determined in a similar manner.

Number of trees in infested territory	15, 906, 398
Assuming that one-fourth bear every year 1 crate per tree, at 50 cents value	$1, 988, 299
Estimated annual loss of 50 per cent	$994, 149
Cost of treatment, spraying, jarring, etc	250, 000
Total	$1, 244, 149

TOTALS.

Apple	$3, 257, 806
Peach	3, 788, 814
Plum, prune, etc	994, 149
Total	$8, 040, 769
Cost of treatments	550, 000
Grand total	$8, 590, 769

LOSSES FROM MISCELLANEOUS FRUIT-TREE INSECTS.

In addition to the more notable insect pests previously indicated, there is a large number of species which in the aggregate cause a very great injury to fruit or tree. Thus, for miscellaneous apple insects, a conservative estimate indicates that about $10,000,000 are lost annually from the attack of such species as canker worms, apple-tree borers, woolly aphis, etc. The pear crop suffers from pear thrips, pear psylla, codling moth, etc., aggregating in all a loss per year of about $1,350,000.

The loss to stone fruits from miscellaneous insect pests is found to be somewhat more than $3,650,000.

Cranberry culture is a relatively small and specialized industry; nevertheless, the losses from insect attack in proportion to the value of the crop is high, amounting to perhaps not less than 25 per cent. Using as a basis the figures furinshed by the American Agriculturist as to yield, the loss from insect attack to the fruit and vine amounts to about $400,000 annually.

The losses to the several crops mentioned from these miscellaneous insects thus total about $15,400,000.

The details for these several calculations are given below.

LOSSES FROM MISCELLANEOUS INSECTS NOT CONSIDERED IN OTHER CALCULATIONS.

Figures of 1900 census taken as a basis except in the case of cranberry insects. Here the figures of yield of fruit as given by the American Agriculturist were used.

Miscellaneous apple insects.

Number of apple trees	201,798,642
Valuation, $1 per tree	$201,798,642
Assuming a total annual injury of 5 per cent each year from such insects as canker worms, woolly apple aphis, green aphis, apple-tree borers, caterpillars, oyster shell and scurfy scales	$10,089,932

Miscellaneous pear insects.

Number of pear trees	17,716,184
Valuation, 75 cents per tree	$13,286,138
Assuming a total annual injury of 10 per cent from such species as pear thrips, pear psylla, pear slug, codling moth, curculio, etc	$1,328,613

Cranberry insects.

The average annual yield of cranberries during the past 4 years was (bushels)	1,057,750
Valuation, $1.50 per bushel	$1,586,625
Assuming a total of 25 per cent loss annually from such species as the yellow and black-head cranberry worms, the fruit worm, etc	$396,656

Loss from miscellaneous insects to all stone fruits.

Total number of trees (peach, plum, prune, cherry, etc.)	147,753,746
Valuation, 50 cents per tree	$73,876,873
Estimated total loss of 5 per cent to value of trees annually	$3,693,843

DECIDUOUS FRUIT INSECTS.

Summary of total losses, including cost of treatment.

Codling moth	$16,716,667
San Jose scale	10,528,265
Peach-tree borers	6,000,000
Grape insects	8,769,905
Plum curculio	8,590,769
Miscellaneous apple insects	10,089,932
Miscellaneous pear insects	1,328,613
Cranberry insects	396,656
Miscellaneous stone fruits	3,693,843
	$66,114,650

RELATIONS OF BIRDS AND MAMMALS TO THE NATIONAL RESOURCES.

By Dr. C. Hart Merriam,
Chief of Biological Survey, U. S. Department of Agriculture.

INTRODUCTION.

In taking stock of our national resources and considering ways and means for their conservation, it should not be overlooked that an important part of the national assets consist of our insectivorous and game birds, our splendid game animals, and our native fur bearers.

VALUE OF BIRDS ON THE FARM.

Birds at all times and in all places are of direct interest to man. Some prey upon the products of man's husbandry, but by far the greater number prey continuously upon insects and rodents—the ever present enemies of agriculture and forestry. While it is impossible to represent by figures the value of our insectivorous and predatory birds, or to present in the form of statistical tables the number of millions saved annually by their labors, it would be a shortsighted policy indeed that would sanction depletion of their ranks. It is safe to say that upon their presence and well-being depend the existence of our forests and the possibility of successful agriculture. In most States an enlightened policy with regard to insectivorous birds already prevails; and there is a growing sentiment also in favor of adequately protecting game birds, not only for their food value and as objects of pursuit by sportsmen, but for their demonstrated value as destroyers of insects, in which capacity some of them take first rank. The recognition of their importance in the latter rôle is comparatively recent, and much remains to be done before the public is educated to an understanding of the nature and full extent of their services, and the losses that will inevitably follow serious diminution of their numbers.

A striking illustration of the value of certain of our native birds and mammals in an emergency was afforded during the invasion by field mice of the alfalfa districts of Nevada in 1907, when mice in the Humboldt Valley increased till in places they reached the astonishing total of 12,000 to the acre, and completely destroyed the alfalfa fields. Several species of hawks and owls, many ravens, gulls, and herons, and numerous foxes, skunks, and coyotes speedily assembled and took up permanent residence in the infected district, where they fed almost wholly on the field mice. Though inadequate by themselves to suppress the plague, they contributed important aid, and had not their numbers been previously reduced by years of persistent persecution, it is almost certain that no plague would have occurred, as they would have prevented the increase of the mice. Furthermore, after the mice had been greatly reduced in numbers by systematic and persistent poisoning (in February, March, and April), they continued to decrease under the continuous attacks of their natural enemies until by August they were actually scarce—indicating the efficiency and value of the service rendered by predatory birds and mammals.

VALUE OF INSECTIVOROUS AND THE SMALLER PREDATORY MAMMALS.

The value of our insectivorous mammals, and of those whose food consists largely of destructive rodents, is less generally understood, and the labor of protecting and preserving them for the benefit of future generations of farmers is rendered correspondingly difficult.

The lesson that every badger in Wyoming, Colorado, Texas, and other western States has a distinct money value to the public, and that the wanton slaughter of one is a crime against good citizenship, is as yet unlearned by the majority of the population. Foxes, skunks, weasels, and in certain regions even coyotes, have their appointed places on the force of nature's policemen, and a knowledge of the part they play and of the nature and extent of the good they do, as well as of the harm, should be universal.

VALUE OF GAME ANIMALS.

Elk and deer, once so numerous and widespread in the United States, have become so diminished in numbers that to the bulk of our citizens venison has become only a tradition. But by the establishment of game preserves, national parks, and national forests, and by the enactment of wise legislation the scale has been already turned, and the perpetuation of these, the most valuable of our large game animals, seems assured. If, however, they are to retain their place among the national resources and are to become a source of pecuniary profit, something more is necessary than to provide for their continued existence. Since they are among the easiest of animals to domesticate, it is believed, and indeed it has been already demonstrated, that they can be reared in small inclosures and on tracts of brushy land not fit for cultivation. Thus extensive tracts of waste land may be put to profitable use, and at the same time our decreasing meat supply may be materially augmented and its price lowered so as to bring fresh meat within the reach of a considerable part of the population now unable to procure it. One deer breeder states that 20 deer may be kept at the cost of keep of a single Jersey cow.

Value of wild game.—The number of wild deer killed annually in the United States is not known, but the annual kill in six of the Northeastern States (Maine, New Hampshire, Vermont, New York, Pennsylvania, and Michigan) is about 35,000. The resulting venison at 20 cents per pound is worth considerably more than a million dollars. To this should be added the value of hides, trophies, and other products of deer. Bear also are killed in these States, and have a material annual value. Besides, in Maine, about 300 moose are killed annually, the meat, hides, and trophies of which are worth at least $25,000.

In the States west of the Mississippi Valley the game mammals comprise several kinds of deer, elk, moose, antelope, mountain sheep, mountain goat, and bear, and the annual kill is very large, but exact statistics as to numbers and values are lacking.

Game birds, including ducks and geese, snipe, plover, and other shore birds, and the various kinds of grouse and quail, are shot in great numbers in every State in the Union, and in the aggregate have an enormous food and pecuniary value.

The annual revenue from hunting licenses is large and is steadily growing. In 1907 resident licenses were required in 21 States, nonresident in 43. From the rapidity with which the license system is spreading, it is obvious that in a very few years it will be general and that the annual revenue from this source alone will exceed $3,000,000—a sum considerably in excess of that required for the support of an ample warden service; so that the returns from sale of licenses will be a source of direct revenue to the State.[a]

VALUE OF WILD FUR-BEARING ANIMALS.

North America was formerly the richest fur-producing region in the world, but now the stock of fur-bearing animals is greatly depleted, and the supply falls far short of the demand. Still, the annual export of raw furs from the United States is valued at from $7,000,000 to $8,000,000, and the furs retained for home manufacture reach an even higher figure, so that it is probably within bounds to say that the present value of the annual catch of furs in the United States is between $15,000,000 and $20,000,000. The growing scarcity of the more valuable fur bearers has produced in the lower grades a great increase in both demand and price. What is needed in the case of this group of mammals is wise husbanding of the wild stock, which everywhere is diminishing under the growing demand for furs and the rapid encroachment on their original domain by our ever-expanding civilization. Under proper restrictions, the stock of fur-bearing animals, particularly in mountainous regions and in the national forests, may, without cost for maintenance, be brought to yield a large annual revenue.

It is fortunate that one of the most valuable of the fur bearers, the silver fox, can be reared in a semidomesticated state, and it is believed that the industry of fox farming is likely to prove a permanent occupation in northern districts where the fur attains its best development.

LOSSES FROM DESTRUCTIVE RODENTS.

Another important lesson to be learned is the need of cooperative effort in reducing the numbers of the small rodents that prey upon our field and garden crops, nursery stock, and planted seeds. The annual losses to agriculture from the ravages of our native rodents—chiefly ground squirrels, gophers, rabbits, prairie dogs, and field

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[a] In Illinois the revenue from sale of licenses in 1907 was $145,905, exclusive of the cost of collection. In California the revenue from sale of licenses in 1907 was $118,427. The total sum actually available for game protection in 1905 was about $1,000,000.

mice—amount to about $37,000,000, to which must be added an even larger sum, estimated at nearly $56,000,000, for the losses caused by European rats and house mice. These small rodents—singly insignificant, collectively an unmitigated pest—are everywhere a steady drain on production, and in places threaten the very livelihood of the small farmer. To rid restricted areas of them is easy, but attempts to rid large areas often fail simply for lack of the necessary cooperation. As at present conducted the war against them is never ending, because when destroyed on a given tract others quickly come in from adjoining lands, so that the work must be repeated again and again, entailing large expenditures without permanent results.

LOSSES FROM THE LARGER CARNIVOROUS MAMMALS.

It has been estimated by stockmen that in Wyoming alone the losses from predatory animals—wolves, coyotes, and cougars—amount to $1,000,000 a year. This is about 3 per cent of the total value of the stock of the State. Assuming that the percentage of loss in the other States similarly infested ranges from one-tenth of 1 per cent to 2 per cent of the value of the stock, the annual loss to the United States is $13,844,000. This estimate does not include the value of game animals killed by carnivorous mammals, which aggregates several million dollars yearly. When the methods of destruction and repression recommended by the Biological Survey and put into practice by the Forest Service are extended over the wolf-infested country, about $7,000,000 may be saved annually.

This report shows that by the preservation and increase of our useful birds and game animals, and by the application of methods developed by the Biological Survey for the destruction of noxious species, millions of dollars may be saved annually; while the breeding of fur-bearing animals and the raising of deer and other game for market suggest what can be done by artificial means to increase natural resources now on the verge of exhaustion.

THE DEVELOPMENT OF GAME AS A NATURAL RESOURCE.

The game of the United States has never been systematically developed. The supply has usually been treated as inexhaustible, to be appropriated or destroyed at the whim of the individual, regardless of the future or the rights and interests of others, and only recently and in a few States has it been developed for the benefit of the people in general. The results of these wasteful methods are matters of common knowledge and are well exemplified in the case of the buffalo.

The actual destruction of the buffalo occupied less than twenty years, as shown by the following estimates of wild buffalo in the United States:[a]

1871 (Hornaday)	5,000,000
1889 (Hornaday)	285
1897 (practical extermination outside of parks)	---
1903 (Baker)	34
1908 (Hornaday)	25

[a] Including the wild herd in Yellowstone National Park as follows: 1889, 200; 1903, 34; 1908, 25.

These figures show clearly the rapidity with which an animal of commercial value may be practically exterminated. What is true of the buffalo is true also, though in less degree, of several other kinds of big game, and of the wild pigeon. Owing to an awakening of public sentiment, destruction has recently decreased to an appreciable extent, and some kinds of game are now more abundant than they were a few years ago. Low-water mark for game in general probably occurred in the early nineties, and is usually placed about 1895, since when, as a result of protection, most species have held their own or have even increased.

CAUSES OF DEPLETION.

The chief causes of depletion may be briefly summarized as: (1) Killing without provision for maintaining the breeding stock; (2) killing during the breeding season, or, in the case of migratory birds, en route to the breeding grounds; (3) killing without limit.

BETTERMENT.

The means of betterment of present conditions are clearly indicated by the causes of destruction just mentioned, and may be stated as follows: (1) Absolute protection during the period of reproduction, and, in the case of migratory game, during the spring journey to the breeding grounds; (2) careful adjustment of the open season so that the annual kill shall not quite equal the annual increase; (3) reasonable regulation of the methods and extent of killing; (4) provision for rearing game in captivity or otherwise, and for caring for wild stock during winter; (5) provision of adequate means for establishing and maintaining the work of game preservation.

The need for effective protection and the best means of securing it are well understood. The chief obstacle is one of finance, and this is being rapidly overcome by a system of hunting licenses which already has been put into successful operation in many parts of the country. The work has passed the experimental stage and has demonstrated not only that game protection can be made self-supporting, but that reasonably accurate estimates are possible as to the returns to be expected in almost any State. Omitting such centers of population as the great cities, it is safe to assume that from 3 to 5 per cent of the total population of the State will purchase licenses if a uniform $1 hunting license is in force. This will create a fund sufficient in almost every State to carry on the work. At least 12 States—Alabama, California, Connecticut, Idaho, Illinois, Michigan, Missouri, Montana, North Carolina, North Dakota, Washington, and Wisconsin—have already reached the point where the work of game protection is self-supporting. Similar results can be accomplished in most of the other States as soon as public sentiment has been awakened sufficiently to demand the necessary legislation. In 1905 the funds for game protection amounted to nearly $1,000.000, of which more than $500,000 was received from fees for hunting licenses, about $350,000 from specified appropriations, and the remainder from receipts from fines and miscellaneous sources.

To what extent game may be developed as a national resource can only be suggested by a few illustrations.

VALUE OF GAME.

The value of game may be direct or indirect. It may yield the State a direct revenue in the form of fees from hunting privileges and leases, and the owner a cash return from its sale for food, hides, trophies, and other products, or, if alive, for purposes of propagation; it may also directly increase the value of land. The principal indirect benefit is from the influx of nonresidents—hunters, photographers, and summer visitors—attracted by its presence, with the resultant employment of guides, boatmen, and camp help, and coincident increase of local business. The permanent financial benefit derived from this source has been thus summarized by Senator W. P. Frye:

In all times of business depressions and distress, financial panics and consequent unemployment of labor, so seriously affecting the country, the State of Maine has suffered much less than any other State in the American Union, mostly, if not entirely, due to the large amount of money left with us by the fishermen, the summer tourist, and the fall hunter—the seeker after change, rest, and recreation.[a]

REVENUE FROM HUNTING LICENSES.

The modern system of hunting licenses in the United States practically began in 1895, and has been gradually extended until at present residents are required by nearly half of the States, and nonresidents by all but 5, to obtain licenses to hunt game. The price of a resident license is usually $1, while that of a nonresident license varies from $10 to $50. The rapid growth of the license system is shown by the fact that in 1903 resident licenses were required in 13 States, nonresident in 31; in 1905 resident licenses were required in 17 States, nonresident in 36; and in 1907 resident licenses in 21 States and nonresident in 43.

Receipts from these licenses have grown from inconsiderable amounts to large sums, which in several States are amply sufficient to support an efficient game warden force, and in a few to provide a large surplus available for the introduction and propagation of game. Thus in 1907 California collected more than $118,000 from the sale of hunting licenses, and Illinois about $145,905.[b] The returns for 1905, the latest year available, are shown in the table on the following page, which, for purposes of comparison, includes also the figures for 1903.

[a] Rept. Comm. Inland Fisheries and Game of Maine, for 1902, p. 21.

[b] Total receipts amounted to $191,943.50, from which have been deducted clerks' fees aggregating $46,038.50.

Number of hunting licenses issued and total fees collected in 1903 and 1905.

State.	1903.				1905.			
	Resident.	Nonresident.	Total licenses.	Total fees.	Resident.	Nonresident.	Total licenses.	Total fees.
Arizona	(a)	(a)	(a)	(a)	(a)	[b] 11	11	$110
Colorado	15,184	34	15,218	$15,930	19,364	30	19,394	19,980
Delaware	(a)	315	315	1,027	(a)	213	213	516
Florida	(a)	....	....	....	(a)	607	607	6,070
Idaho	12,370	267	12,637	14,105	15,010	112	15,122	16,050
Illinois	95,000	250	95,250	98,875	161,164	459	161,623	127,988
Indiana	....	....	....	....	13,200	116	13,316	14,998
Iowa	(a)	....	....	....	(a)	....	....	....
Kansas	(a)	(a)	(a)	(a)	42,000	20	42,020	42,300
Kentucky	(a)	....	....	....	(a)	....	....	....
Louisiana	(a)	(a)	(a)	(a)	(a)	....	....	852
Maine	(a)	1,697	1,697	25,465	(a)	2,413	2,413	33,155
Maryland	(a)	26	26	154	278	69	347	805
Michigan	19,061	45	19,106	15,421	14,878	105	14,983	24,942
Minnesota	8,910	333	9,243	14,205	15,861	309	16,170	20,211
Missouri	(a)	(a)	(a)	(a)	47,746	65	47,811	48,721
Montana	(a)	72	72	1,690	30,087	133	30,220	32,662
Nebraska	3,744	84	3,828	4,584	5,202	140	5,342	6,602
New Hampshire	(a)	135	135	1,350	(a)	469	469	4,690
New Jersey	(a)	301	301	3,161	(a)	264	264	2,772
New York	(a)	....	....	....	(a)	48	48	505
North Carolina	(a)	916	916	9,389	(a)	987	987	10,117
North Dakota	11,574	123	11,697	11,756	13,187	96	13,283	12,290
Ohio	(a)	17	17	429	(a)	31	31	473
Oregon	(a)	(a)	(a)	(a)	19,856	138	19,994	21,236
Pennsylvania	(a)	....	....	....	(a)	....	....	....
South Dakota	....	....	....	....	615	371	986	5,278
Tennessee	(a)	40	40	200	(a)	....	....	417
Utah	(a)	30	30	300	(a)	9	9	225
Vermont	(a)	(a)	(a)	(a)	(a)	28	28	420
Virginia	(a)	348	348	3,480	(a)	355	355	3,550
Washington	14,982	(c)	14,982	14,982	26,015	(c)	26,015	26,271
West Virginia	(a)	29	29	464	(a)	21	21	336
Wisconsin	78,164	659	78,823	90,169	73,474	781	74,255	88,019
Wyoming	299	158	457	8,199	2,347	168	2,515	12,149
Total	259,288	5,879	265,167	335,335	500,284	8,568	508,852	584,640

[a] No license in force.
[b] For rate and other details, see Circular 54, Biological Survey, United States Department of Agriculture, 1906, pp. 9, 13.
[c] Nonresident licenses inseparable from resident licenses.

Direct income from licenses.—In the States which have adopted both resident and nonresident licenses the percentage of licensed hunters in 1905 varied from one-fourth of 1 per cent of the population in South Dakota to more than 10 per cent in Montana, but in most of the States it was approximately 3 per cent. In every case in which the proportion was less than 1 per cent the falling off was evidently due to imperfect license laws. The figures in the foregoing table furnish the best basis at present available for estimating the total number of persons hunting in the United States and the amount of revenue obtainable under a uniform hunting-license law. The population of the United States, exclusive of Alaska, Hawaii, and Porto Rico, on June 1, 1905, as estimated by the Census Bureau, was 82,565,005. Three per cent of this number represents approximately the number of persons who hunt. In other words, the total number of persons who hunted in the United States in 1905 may be estimated at 2,500,000 to 3,000,000; hence if a uniform law requiring a $1 resident license had been in force in all the States the total revenue collected from this source would probably have been not less than $3,000,000.

ILLUSTRATIONS OF INCREASE IN VALUE OF LANDS DUE TO PRESENCE OF GAME.

Income from lease of hunting privileges.—In North Carolina shooting on another person's land without permission of the owner is prohibited by the game laws. Under this provision a system of leasing hunting privileges has grown up in certain counties during the last twenty years, especially in the north-central part of the State—in Davidson, Guilford, Forsyth, Moore, and Randolph counties. Owners of adjoining farms agree to permit no hunting on their land except by the lessee or his friends in consideration of the payment of a fixed sum or of all the taxes on the property included.

Guilford County, which may be taken as an illustration, has an area of 680 square miles, a little more than half that of Rhode Island. It contains two important towns, Greensboro and Highpoint. Its population in 1900 was about 40,000. On its farms, which average 100 or 200 acres in extent, wheat, corn, cotton, fruit, and vegetables are the principal crops. In 1904 about 150,000 acres, more than one-third the area of the county, was under lease for private game preserves, each preserve ranging from a few hundred to 12,000 or 15,000 acres. Some leases run for one year; others for five or ten years, with the privilege of renewal. The amounts paid for rental vary from 5 to 10 cents, based on the ordinary tax rate for lands outside the towns, which rate averages about 7 cents per acre. Recently a sum amounting to double the tax rate, or even more, has been paid by some lessees. More than one-third of the total real estate tax of the county, exclusive of that of the towns, is paid in this way by lessees of hunting privileges, who, in some cases, assume also special township school taxes. In other words, by merely keeping trespassers off their lands and uniting with their neighbors in leasing hunting privileges, farmers may be relieved entirely from real estate taxes and may perhaps, in addition, receive each year a substantial amount in cash.

Increase in value of marsh lands due to presence of game.—The marsh lands of California where ducks are abundant have greatly increased in value with the increase in popularity of duck shooting during the last fifteen years. In 1907 more than 100 clubs owned or leased game preserves for shooting purposes. The total area of these preserves is unknown, but it is probably not less than 160,000 acres, or approximately 250 square miles, and the preserves vary in size from a few hundred acres to 46 square miles. The capital invested probably amounts to $5,000,000 and comprises not only the value of the land (in case of ownership by the club), but also leases and such improvements as club houses, farms, and artesian wells, besides boats, arks, decoys, and other hunting paraphernalia. The value of the property may vary from a few hundred dollars, in case of leased grounds, up to a million dollars in case of grounds owned by a club which maintains a club house and develops the hunting facilities of the marsh to the highest degree possible.

Duck preserves in California comprise both fresh and salt water marshes, and may be roughly divided into six groups or districts. The two most important of these are the Suisun marshes on the north side of Suisun Bay, in Solano County, occupied by 12 or 15 clubs, and the marshes in southern California, in Los Angeles and Orange counties, occupied by some 36 clubs. Thirty of the southern California preserves have a combined area of about 40 square miles, and represent an investment approximating $3,000,000.

In 1893 one of the first clubs organized in the State leased 3,000 acres of land in the Suisun marshes for a term of four years at $1,200 per year, or an annual rental of 40 cents per acre. A few years ago a syndicate is said to have purchased 5,000 acres in the same marshes for $100,000, or $20 per acre; and four-fifths of this tract have since been sold or disposed of to members of shooting clubs at prices ranging from $40 to $50 per acre. Similar increases in values have occurred in southern California. In other words, lands suitable for duck preserves, which a few years ago were of little or no value, now command prices of $40 per acre and upward, and the improvements on such property in several instances aggregate thousands of dollars.

Annual kill of big game in the northeastern States.—Moose and deer are the only big game animals which can now be killed east of the Mississippi River. Moose hunting is permitted only in Maine and Minnesota, and deer hunting north of the Mason and Dixon line only in Maine, New Hampshire, Vermont, New York, Pennsylvania, Michigan, Wisconsin, and Minnesota. Statistics of the actual number of moose and deer in any State, or of the annual increase, are not available, and only one State—Vermont—publishes a record of the number annually killed. Statistics of the shipment of big game are collected in Maine and New York, however, and from these, and from other data for Pennsylvania and Michigan, it is possible to estimate the number annually killed in several of the States.

Figures for the decade from 1897 to 1906 are as follows:

Number of moose shipped in Maine (Bangor and Aroostook Railroad).

1897	139	1902	224
1898	202	1903	232
1899	166	1904	222
1900	210	1905	207
1901	259	1906	198

Number of deer killed or shipped in four States.

Year.	Deer killed.		Deer shipped.				
			Maine.		New York (Adirondacks).		
	Vermont.	Michigan (estimated).	Bangor and Aroostook Railroad.	All roads.[a]	Carcasses.	Saddles.	Heads.
1897	103		2,940				
1898	131		3,377				
1899	130		3,756				
1900	123	2,000	3,379		1,020	89	95
1901	211	6,000	3,882	6,233	1,062	103	121
1902	403		4,495		1,354	113	193
1903	753	22,000	3,786	5,853	1,961	145	188
1904	531	7,000	3,558	5,475	1,618	124	152
1905	497	7,000	4,634	6,799	2,196	108	180
1906	634	10,000	3,377	5,494	2,413	108	102

[a] Statistics from the Maine Sportsman.

Explanation of the table.—Statistics of the amount of game killed, as an index to relative abundance, are not always directly comparable. even in adjoining States, for the reason that the three factors of length of season, bag limit, and license fees may conceal or exaggerate differenees in the returns from different States, or the fluctuations from year to year in the same State. For example, the deer season in Vermont lasts 6 days, that in Maine 76 days; in Vermont each hunter may kill one deer, while in Maine eaeh may kill two; residents of Maine and Vermont may hunt without a license; in Michigan eaeh must pay $1.50 for the privilege.

Vermont.—As an illustration of the effects of protection and restoeking, the statistics of deer killed in Vermont are the most accurate and interesting of any in the United States. Thirty years ago deer in Vermont had been practically exterminated, except in the extreme northeastern corner (in Essex County). About this time a few deer were liberated in the southern part of the State, and these two centers (Essex and Rutland counties) have supplied the stock which has now spread over the State. Deer hunting was prohibited for a number of years, the first open season being that of 1897. The table indicates that from 1897 to 1906 the annual kill increased more than 600 per eent. The actual abundance of the animals must also have greatly increased, for the open season, originally the entire month of Oetober (1897–1898), was shortened after 2 years to the last 10 days in October (1899–1903), and 4 years later to the last 6 days in Oetober (1904–1906). Moreover, since 1904, nonresidents have been required to pay a license fee of $15, and the number of visitors from other States who formerly visited Vermont to hunt deer may have been reduced in consequence of this additional expense.

Michigan.—Fluctuations in the figures for Michigan are due to a combination of eauses, artificial as well as natural. In 1900 the season opened with sufficient snow for tracking, and in consequence large numbers of deer were killed. In the following year changes in the game law prohibited sale and reduced the number of deer allowed each hunter to three. These circumstances explain in large measure the reduction of 50 per cent in the number of deer killed. The falling off in 1904 was due to a light snow, and that in 1905 to the same cause, and probably also to the fact that the cost of the resident hunting license was doubled.

Maine.—The only statistics available for a period of years are those for shipments over the Bangor and Aroostook Railroad. But in reeent years data are available from other railroads also, and these indicate that the returns from the Bangor and Aroostook Railroad should be eonsiderably augmented to represent the total number of deer shipped in the State. For example, in 1905 and 1906 the figures for the Bangor and Aroostook Railroad are 4,634 and 3,377, respeetively, while those for all the roads are 6,799 and 5,494, respeetively.

New York.—In New York the deer shipments from the Adirondaeks are reported as earcasses, saddles, and heads, but it is impossible to tell exactly how many deer are shipped, for the reason that a saddle and a head may or may not represent parts of the same animal. In addition to the deer killed in the Adirondaeks, a few are obtained in other counties, and about 50 or 100 annually on Long Island. In 1895 and 1896 the fish, game, and forest commission reported the total number killed in the State at 4,900 and 5,247, respectively, but in recent reports the annual kill is not estimated. In view of the fact that since 1895 shipments have more than doubled, 5,000 may be accepted as a conservative estimate of the number killed in 1906.

Estimates of annual kill of deer.—Estimates of the number of deer killed in 1906 in Maine, Vermont, Pennsylvania, and Michigan have been made by the state game commissioners. It is probable that the number killed in New York is not less than 5,000, and that in New Hampshire the season's yield is approximately the same as that in Vermont. On this basis the total number of deer killed in these six Northern States is about 35,000, as follows: Maine, 18,000; New Hampshire, 600; Vermont, 634; New York, 5,000; Pennsylvania, 800; Michigan, 10,000. Total, 35,034.

Value of venison.—Assuming the average weight of a dressed deer to be 150 pounds,[a] the total quantity of venison produced in these six States in 1906 was about 5,255,000 pounds. At an average value of 20 cents a pound this would be worth $1,051,000.

FINANCIAL BENEFITS ACCRUING FROM PRESENCE OF HUNTERS AND SUMMER VISITORS.

In 1902 the commissioners of inland fisheries and game in Maine endeavored to ascertain the number of nonresidents who visited the State (exclusive of seaside resorts) for the purpose of fishing, spending vacation, or hunting, and the amount of money left in the State by such visitors. Of sixteen counties in the State, no returns were received from Lincoln and Sagadahoc, and only incomplete returns from Aroostook, Franklin, Penobscot, Piscataquis, Somerset, and Washington. According to the statistics collected, the visitors in 1902 numbered 133,885, and paid for board $1,371,201 and for guides $300,000. Their presence involved the employment of 3,965 persons—1,401 males and 2,564 females. The figures for receipts, wages, and capital invested are as follows:

Receipts, wages, and capital invested on account of summer visitors in Maine, 1902.

Cash received for board of visitors	$1, 371, 201
Wages for male help	153, 541
Wages for female help	114, 393
Valne of boats, canoes, and launches	815, 048
Money invested in summer hotels, cottages, and hunting camps	5, 541, 274

Statistics of the amount of money paid for railroad, electric car, and steamboat fares, for team hire, and for other purposes are not available. The commissioners add:

> It is believed that a most conservative estimate would be that these visitors leave at least $100 each, on an average, in the State. Indeed, some of them spend more than $50 a day, and a good many of them spend several thousand dollars each year.

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[a] That these estimates are conservative is shown by the fact that the average weight of dressed deer killed in Vermont in 1905 was 198 pounds, while in New York the heaviest bucks occasionally weigh 265 or rarely 285 pounds. The value of venison varies greatly with the market where it is sold.

It will be seen, therefore, that if they spend on an average $100 each, over $13,000,000 are left by them in Maine each year; or if they spend but $50 each they leave six millions and a half of money with us annually. (Rept. Comm. Inland Fisheries and Game, 1902, pp. 34–35.)

FARMING DEER AND OTHER GAME.

As a result of the growing scarcity of game the supply of venison and game birds is wholly inadequate to the demand, and the time seems to have arrived for the propagation of game on private preserves or game farms.

The raising of venison and game birds for market is as legitimate a business as the growing of beef and mutton, and state laws when prohibitory, as many of them are, should be so modified as to encourage the industry of game breeding. Deer and elk may be raised to advantage in forests and on rough bushy ground unfit for either agriculture or stock raising, while ducks and other waterfowl may be bred on otherwise valueless marshes, so that large areas of waste land may be utilized for profit. An additional advantage is that the business is well adapted to landowners of small means. Besides supplying game for market, breeders of game mammals and birds may find even greater profit in raising them for stocking preserves. For many years to come the demand for this purpose is likely to exceed the supply.

VALUE OF FUR-BEARING ANIMALS.

The United States, with Alaska and outlying islands, forms a large part of what was once the richest fur-producing region in the world. Its present output is still large, but it is obtained with increasing difficulty and the future is very uncertain. Excepting the arid and treeless parts of the West, practically all the territory now included in the United States was inhabited originally by animals bearing valuable pelts. In the Eastern States these animals were speedily reduced in numbers or driven to less accessible regions, and their pursuit as a business soon passed to the Western and Northern States.

With the purchase of Alaska in 1868 the United States became more than ever identified with the fur trade, for in addition to great quantities of less important kinds this great territory produced a majority of the world's supply of fur seal and sea otter skins and a considerable proportion of silver-black fox, three of the most valuable of furs. But even in Alaska the pace set was too rapid, and the natural increase of the animals failed to keep up with it.

Although the ranges of the more important fur-bearing animals have become more and more restricted, and the animals themselves have rapidly diminished in numbers, still the annual volume of trade as expressed in dollars and cents has remained remarkably uniform, even showing a tendency to increase. Thus the exports of raw furs in 1890 amounted to $4,661,934, in 1895 to $3,923,130, in 1905 to $6,599,222, and in 1906 to $8,002,282. For the twenty-five years from 1875 to 1900 the average annual export value of furs was more than $4,000,000, the total for this period, therefore, being over $100,000,000. These figures are explainable only by the fact that many furs have doubled, trebled, and even quadrupled in price; so that, although total receipts do not fluctuate greatly, the number of pelts marketed annually is much smaller than formerly.

As indicating the extent of the annual fur trade in the United States, the following table is given, being an estimate of the number and value of certain of the more important furs produced in the United States during 1900:[a]

Designation.	Number of skins.	Value.
Beaver	8,000	$39,860
Fur seal	24,000	660,000
Mink	578,000	810,000
Muskrat	4,035,000	565,000
Otter	14,600	93,260
Sea otter	330	133,980
Total value	....	$2,302,100

The accompanying table shows the value of furs exported yearly from the United States since 1890:

Value of furs exported from the United States, 1890–1907.[a]

Year.	Value.	Year.	Value.	Year.	Value.
1890	$4,661,934	1897	$3,284,349	1904	$5,422,945
1891	3,236,705	1898	2,986,970	1905	6,599,222
1892	3,586,339	1899	3,092,846	1906	8,002,282
1893	3,699,579	1900	4,503,968	1907	7,139,221
1894	4,238,690	1901	4,404,448		
1895	3,923,130	1902	5,030,204	Total exports, 1890–1907	$83,794,115
1896	3,800,168	1903	6,181,115		

[a] From Commerce and Navigation, Bureau of Statistics, U. S. Dept. Commerce and Labor.

Average annual value for these eighteen years, $4,655,228.

INCREASED DEMAND FOR AND PRODUCTION OF LOW-GRADE FURS.

That the supply of the better grades of furs is unequal to the present demand is proved not only by the higher prices they bring, but also by the steady increase in the quantity of cheaper furs used and by the additional fact that these cheap furs have gradually brought higher and higher prices, until now they command prices equaling or exceeding those formerly paid for better furs. Very large quantities of cheap furs are manufactured in the United States, in addition to those sold in the London market, but statistics of the home-manufactured product are not available.

The fur of skunks, for example, was practically unnoticed prior to 1850. In 1851 the Hudson Bay Company offered 1,453 skunk skins for sale, and for twenty years the annual number sold was scarcely more than 10,000. In 1891 the number had increased to upward of 400,000, and the increase, both in number and price, has continued to the present time, the number reaching 1,368,475 skins in 1907, as shown by the following table:

[a] From Ann. Rept. U. S. Comm. Fisheries, 1902, p. 287.

Skunk fur sold in London market.[a]

Year.	Number of skins.	Advance in price.	Decline in price.
		Per cent.	*Per cent.*
1891	422,398	(b)	
1892	635,800		10
1893	575,472	11½	
1894	739,228		20
1895	542,885	(c)	
1896	796,750		32½
1897	872,323	(b)	
1898	482,130	22½	
1899	426,610	60	
1900	695,686	16	
1901	696,961		12
1902	973,695	25	
1903	987,550	5	
1904	911,923		12½
1905	952,549	25	
1906	1,225,582		
1907	1,308,475		

[a] Compiled from London sales. [b] Stationary. [c] No report.

Muskrat fur has been in use much longer than skunk, but for years was little valued. Now it has been computed that about 5,000,000 animals are killed annually. The total product of this fur in the United States is now worth at least $1,000,000 annually.

Muskrat fur sold in London market.[a]

Year.	Number of skins.	Advance in price.	Decline in price.
		Per cent.	*Per cent.*
1891	1,832,985	10	
1892	2,182,785		40
1893	3,144,236	5	
1894	3,662,076		(b)
1895	2,565,157		15
1896	3,028,683	40	
1897	2,341,283	10	
1898	2,674,651	(c)	
1899	1,763,237		10
1900	3,508,352		(a)
1901	3,408,447		10
1902	4,733,479	(c)	
1903	4,321,459	35–70	
1904	4,477,937	(d)	
1905	5,227,461		15
1906	4,993,080		
1907	3,391,494		

[a] Compiled from London sales. [b] Slight. [c] Stationary. [d] About stationary.

Increased prices have given greater incentive to the pursuit of fur-bearing animals, so that the work of extermination begun decades ago has progressed in recent years with greater and greater rapidity. The most conspicuous examples of rapid decrease are those of the sea otter and the fur seal. From 1873 to 1885 the annual catch of sea otters in Alaskan waters was from 3,000 to 4,000 skins. Estimating these conservatively as worth $300 each, the total yearly value was about $1,000,000. In 1895 the catch had dropped to 887, and in 1905 to 320, a decrease of approximately 90 per cent in twenty years. The Pribilof fur seals, which once yielded millions of dollars, have decreased enormously during the past twenty years. Thus the average yearly catch on the islands from 1868 to 1889, inclusive, was

104,834, while for the years 1904–1906 it averaged 13,249. In other words, an important source of revenue in a region otherwise unproductive is gradually being destroyed.

Comparison of the value of the total shipment of furs from Alaska for the past five years, 1903–1907, with the figures for corresponding previous periods, emphasizes the fact that the actual number of furs formerly exported annually was so much greater than now that even at the comparatively small prices then prevailing the value of the exports for each of the two periods from 1881 to 1885, inclusive, and from 1886 to 1890, inclusive, was practically five times as great as during the past five years.

Shipments of furs from Alaska.

Year.	To foreign countries.	To United States.	Total shipments.
1903	$6,559	$423,606	$430,165
1904	21,099	449,497	470,596
1905	7,331	494,764	501,095
1906	12,466	494,911	507,377
1907	1,114	646,652	647,766
Total shipments for past five years			$2,556,999
Total shipments 1881–1890 [a]			23,725,783
Total shipments 1871–1880 [a]			21,049,940
Total shipments 1868–1870 [a]			3,743,206

[a] Population and resources of Alaska, Eleventh Census (1890), p. 215, 1893.

DECREASE AND REMEDIES.

Accurate figures showing the rate of decrease of the wide ranging smaller fur-bearing animals are not obtainable, but most of these animals are everywhere greatly reduced in numbers, and throughout a large part of their original range are practically extinct. The beaver, for example, which was formerly abundant over three-fourths of North America, is now extinct in more than half of this area, and over the remainder occurs only in relatively small numbers. In 1870 the number of beaver skins exported from North America was approximately 225,000; in 1890 it had diminished to 82,000. Other fur bearers, as foxes, martens, fishers, and land otters, are similarly decreasing, as shown by the number of skins exported.

Throughout the length and breadth of coniferous forests of the Rocky Mountains from Montana to New Mexico, and of the Sierra-Cascade Range from the State of Washington to southern California, fur-bearing animals were formerly so abundant as to form the principal source of revenue to the early explorers and settlers. Now they are so scarce as to be unimportant. The cause of this great decrease over more than 150,000,000 acres of our public domain is not so much overtrapping as overgrazing. Overgrazing by sheep has converted many thousands of miles of brushy slopes and mountain meadows into barren deserts, destroying the cover which sheltered the hordes of small mammals and birds on which the fur bearers subsist.

The practical extinction of fur-bearing animals in areas suitable for settlement and for the development of agriculture or manufacturing is inevitable, but in areas not needed for the development of industries there is no necessity for their utter depletion. The greater part of the vast territory of Alaska and thousands of square miles of national forests, national parks, and other wild forest lands in the United States when not injured by overgrazing offer ideal conditions for the continued existence of these species. These animals, if fostered in such regions, will not only prove a valuable asset in themselves but in many localities will add to the value of the forest, for most of them prey upon the insects and gnawing animals which are constantly at work injuring trees and devouring seeds on which the future life of the forest depends.

The remedy seems to lie in the prevention of overgrazing and in the enactment of laws limiting the open season for trapping. Many of the States have already realized the necessity for such legislation and have acted accordingly. It remains only for other States and the National Government to follow their example in order to provide for the preservation and utilization of an important natural resource which, at no cost for maintenance, may be made to yield a substantial annual revenue.

A good example of such protective laws is the one passed by the State of Michigan in 1897, extracts of which are here given.

AN ACT For the protection of certain fur-bearing animals.

[Act 86, P. A. 1897.]

The people of the State of Michigan enact:

(518) Paragraph 5825. SECTION 1. It shall not be lawful for any person or persons to trap, catch, kill, or destroy, or attempt to trap, catch, kill, or destroy, by any means whatsoever, any beaver in this State until the thirty-first day of December, nineteen hundred ten.[a]

(519) Paragraph 5826. SEC. 2. No person shall hunt, trap, catch, kill, or destroy, or attempt to hunt, trap, catch, kill, or destroy, within this State, by any means whatsoever, any otter, fisher, or marten, from the first day of May in each year to the fifteenth day of November following thereafter.

(520) Paragraph 5827. SEC. 3. It shall be the duty of every person having knowledge or information that acts amounting to a violation of this act have been committed to at once report the same to the State game and fish warden, or to the deputy game and fish warden residing in or having supervision over the county wherein the alleged violation was committed, or to the prosecuting attorney of such county, whose duty it shall be to forthwith prosecute the offender.

(521) Paragraph 5828. SEC. 4. Any person who shall be found guilty of a violation of any provisions contained in the foregoing act shall, upon conviction thereof, be deemed guilty of a misdemeanor, and be punished by a fine of not less than ten dollars, nor more than fifty dollars, and the costs of prosecution, or imprisonment in the county jail not to exceed ninety days, or both such fine and imprisonment, in the discretion of the court.

AN ACT to protect mink, raccoon, skunk, and muskrats during the months of September and October in each year, and to provide a penalty for the violation thereof.

[Act 201, P. A. 1899.]

The people of the State of Michigan enact:

(522) SECTION 1. That it shall not be lawful for any person or persons to trap, hunt, shoot, or kill any mink, raccoon, skunk, or muskrat in this State during the months of September and October in each year; (*a*) except it be on his own premises, and such person can prove that the said animal was damaging him: *Provided, however*, That this act shall not be construed so as to repeal act number twenty-seven of the session of eighteen hundred ninety-seven; *Provided further*, That nothing in this act shall prevent water-power owners from

[a] Am. 1905, act 204.

killing or destroying muskrats within one-half mile of any water power in this State: *And provided also*, That nothing in this act shall be construed to prevent owners of dykes from killing or destroying muskrats on or along such dykes when damaging such dykes.

(523) Sec. 2. Any person who shall be found guilty of violating any of the provisions of this act shall, upon conviction thereof, be deemed guilty of a misdemeanor, and shall be liable to a fine of not more than one dollar and costs of prosecution for each and every animal killed.

ECONOMIC RELATIONS OF BIRDS.

So important are birds as conservators of the forest and as protectors of farm crops that neither forestry nor agriculture could be successfully practiced without their aid. As year by year the value of farm and orchard products increases, so the value of birds as conservators of the farmers' interests increases. The need of adequate legislation in favor of insectivorous birds was never so great as now, and it is probable that in the future protective laws will be still more important. Insectivorous birds spend their lives in the pursuit of insects, vast numbers of which are required for their support. The seed-eating birds attack noxious weeds at the most critical stage of their existence, during and after seeding, and as seeds constitute for these birds the staff of life the quantity they destroy is incalculable. No labor-saving machine has ever been devised that equals the value to the farmer of the seed-eating birds. The predatory birds, mainly hawks and owls, render an even greater service, keeping down the hordes of mice, gophers, ground squirrels, and other vermin that destroy crops. It is not too much to say that such outbreaks as the recent field-mouse plague in Nevada would never occur were it not that our predatory animals have been so greatly reduced by ruthless killing that they are no longer able to prevent the increase of these pests.

A good illustration of the costliness of popular misconceptions as to the economic status of some of our common birds and mammals may be found in the so-called "scalp act" of Pennsylvania, passed in 1885. This act provided a bounty of 50 cents each on hawks, owls, weasels, and minks killed within the state limits and a fee of 20 cents to the notary or justice taking the affidavit. As a result about $90,000 was paid in bounties during the year and a half subsequent to the passage of the act. This amount represents the destruction of at least 128,571 of the above-mentioned animals, most of which were hawks and owls. Estimating that 5,000 chickens are annually killed in Pennsylvania by hawks and owls, and that their value is 25 cents each (a liberal estimate in view of the fact that a large proportion of them are killed when very young), the total loss of poultry in a year and a half would be about $1,875. It thus appears that $90,000 were paid by the State of Pennsylvania to save its farmers a loss of less than $2,000. But this estimate by no means represents the actual loss to the farmer and taxpayer of the State. It is safe to say that every hawk and owl yearly destroys at least 1,000 mice, or their equivalent in insects, and that each mouse or its equivalent so destroyed would cause the farmer a loss of 2 cents per annum. Thus the lowest possible estimate of value to the farmer of each hawk and owl would be $20 a year. The actual loss to the State, therefore, by the destruction of 128,571 of its benefactors in a year and a half was about $3,850,000. Even these figures, enormous as they are, do not represent the entire loss to the State, since the destruction of such a vast number of predaceous birds and mammals is sure to be followed by a corresponding increase in the number of mice and insects, their natural prey, and years must elapse before the balance of nature thus destroyed is restored.

LOSSES FROM CARNIVOROUS MAMMALS.

Wolves are still numerous in parts of Wyoming, Montana, the Dakotas, Nebraska, Kansas, Colorado, New Mexico, Arkansas, Oklahoma, Missouri, Michigan, Wisconsin, and Minnesota, and yearly destroy great numbers of cattle and horses. Coyotes are numerous over a still larger area and destroy vast numbers of sheep, while cougars, or mountain lions, in certain parts of the West kill annually so many colts that they must be reckoned with as an economic factor of considerable importance.

Bounties have had little effect in exterminating predatory animals, or even in permanently reducing their numbers. Thus, in Wyoming, where liberal bounties for wolves and coyotes have been paid for the past twelve years, both animals are still numerous. This is shown by the following table:

Bounty records for twelve years in Wyoming.

Year.	Number of wolves on which bounty was paid.	Bounty per wolf.	Total amount paid in bounties.
1895	1,699	$3	$5,097
1896	3,365	3	10,095
1897	897	4	3,588
1898 [a]	....	....	....
1899 and 1900 [b]	4,908	3	14,724
1901 and 1902 [b]	4,480	3	13,440
1903 and 1904 [b]	2,256	5	11,280
1905 and 1906 [b]	3,214	3	9,642
Total for 11 years	20,819	....	67,866

[a] Species not reported separately; $14,160.25 paid on wolves, coyotes, and mountain lions.
[b] Biennial reports not separated by years.

In 1906 Mr. Victor Culberson, president and manager of the G. O. S. Cattle Company, on the Gila Forest Reserve, Grant County, N. Mex., estimated the loss of cattle killed by wolves to be 10 per cent of the herd. This loss was sustained under a bounty system of $20 per head for wolves, as shown in the following table:

Bounty records for four years in Grant County, N. Mex.

Year.	Number of wolves on which bounty was paid.	Bounty per wolf.	Total amount paid in bounties.
1902	11	$20	$220
1903	33	20	660
1904	54	20	1,080
1905	29	20	580
Total for 4 years	127	....	2,540

Although no exact figures are available, the following estimate is probably not far from the truth and is at least safely conservative:

A prominent stockman of Wyoming estimates the losses from predatory animals in that State at $1,000,000 a year, or about 3 per cent of the total value of the stock of the State. Assuming that the percentage of loss in other States infested by wolves, coyotes, and cougars ranges from one-tenth of 1 per cent of the value of the stock to 2 per cent (the estimate being made from known conditions), the annual losses aggregate as follows:

Range cattle	$5,889,000	
Horses and mules	1,636,000	
Sheep	4,152,000	
Hogs	584,000	
Goats	83,000	
		$12,344,000
Poultry (by coyotes, wildcats, foxes, mink, weasels, etc)		1,500,000
Total		13,844,000

This estimate does not include the game animals destroyed by carnivorous mammals, the value of which aggregate several million dollars yearly.

Thus the combined losses of stock and wild game from predatory mammals, especially from wolves and coyotes, amount to many millions annually. The extermination of these animals under present conditions is not possible, nor indeed is it necessary, since by energetic and concerted action throughout the infested States their numbers can be permanently reduced and the losses kept down to a minimum, with or without the offering of bounties. It is safe to say that by the methods recommended by the Biological Survey, and actually put into effective operation in and adjacent to the national forests by the Forest Service, fully half this loss, about $7,000,000, may be saved each year.

LOSSES FROM RODENTS.

Prairie dogs.—Prairie dogs infest most of the open plains country of the United States from near the Canadian boundary south into Mexico, and from a little east of the one hundredth meridian westerly to the foot-hills of the Rocky Mountains, and also a considerable part of the plateau country still farther west. Their colonies—"dog towns," as they are commonly called—vary in extent from a few acres to thousands of square miles and are inhabited by thousands and in some cases by millions of animals. Colonies 20 to 30 miles in length are not rare, and in Texas one is known which measures 250 miles one way by 100 to 150 the other, covering an area of about 25,000 square miles. The number of holes in use in each acre varies from a few to upward of a hundred, and probably averages at least 25. In winter and early spring the usual number in each hole is two (a pair), while after the birth of the young the number is at least quadrupled, and then decreases with the advance of the season, as the young are killed by their enemies. It is certainly a conservative estimate to assume the average number of animals per acre to be 25. On this assumption, the number of prairie dogs in the great Texas colony must be at least 400,000,000.

It is estimated that 32 prairie dogs consume as much grass as 1 sheep, and 256 prairie dogs as much as 1 cow. On this basis the grass annually eaten by these pests in the great Texas colony would support 1,562,500 head of cattle. It is no wonder, therefore, that the annual loss from prairie dogs is said to range from 50 to 75 per cent of the producing capacity of the land and to aggregate millions of dollars. The annual rental value of range land for grazing purposes is from 8 to 15 cents per acre. At an average damage of 5 cents per acre the loss amounts to $1,500,000 per year. But grass is by no means the only crop injured by prairie dogs, for they are extremely destructive also to grain and other products of the soil. The annual loss to farmers from this source probably reaches $1,000,000, making the total annual loss about $2,500,000.

In the open grazing regions where natural conditions prevail prairie dogs usually increase slowly and do not extend their range rapidly. But the settlement of an infested district usually results in a large increase of the food supply and is followed by a rapid extension of range and great increase in the numbers of the pests. Even in areas where they were not particularly numerous previous to the arrival of the farmers, they soon become so abundant that without some cheap and successful method of destroying them profitable agriculture becomes impossible.

In the State of Kansas in 1901, 2,500,000 acres were occupied by prairie-dog colonies. Here as elsewhere the animals damaged the pasture fully 50 per cent, the actual loss amounting to half the rental value of the land, which ranged from 4 to 12 cents per acre. The annual loss to the cattle owners of the State was estimated at $100,000, and the loss to crop producers at nearly as much more. In 1902 the State took the matter in hand and organized a campaign of extermination. The State furnished poison at cost of manufacture, and the work was done under township supervision, the funds being raised by taxation. The total expense, distributed over five years (1902–1906), was about $85,000, or slightly more than 4 cents per acre, as a result of which the prairie dogs were destroyed on at least 2,000,000 acres of infested land.

The good effects on the pasturage were apparent the first year after the prairie-dog town was destroyed, especially where the mounds were leveled. New grass came in on the bare spots and grew luxuriantly. Cattle preferred the parts of the pasture where the "dog town" had been located; whereas when the dogs were present these had been carefully avoided. The sustaining capacity of the land was greater than ever before and a large increase was noted in the selling value. The annual saving to the people of western Kansas is fully double the total cost of the entire work of extermination. It is obvious, therefore, that by the systematic use of well-tried methods over the country now suffering large annual losses from prairie dogs the total of these losses may be easily reduced by at least $1,000,000.

Ground squirrels.—Ground squirrels occur almost everywhere from the Mississippi Valley to the Pacific Ocean, and one species ranges east to Indiana and southern Michigan. The extent of the area they inhabit collectively is about 1,900,000 square miles, or 1,216,000,000 acres. The more destructive species occupy about 825,000 square miles, or 528,000,000 acres, of which 115,000,000 acres are in crops and 413,000,000 acres in range and waste lands.

Ground squirrels rank among the most destructive of North American mammals, causing an annual loss to grain and other crops of about $10,000,000, fully half of which may be saved by the general adoption of methods of poisoning and trapping recommended by the Biological Survey.

The present annual losses in the infested States of the Missouri-Mississippi valley vary from less than 1 per cent to 2 per cent of the grain crop; but in the Sandhills region of western Nebraska and Kansas the loss is so great that in places it is hardly worth while to plant. From Montana and Colorado westward to Washington, Oregon, and California the loss amounts to from 2 to 10 per cent of the value of the grain crop.

Besides the injury to cultivated crops, ground squirrels where abundant do considerable damage to grazing lands by eating the grass and covering it with mounds. This loss is not included in the above estimate of $10,000,000.

The economy of destroying ground squirrels on agricultural lands is not open to question. By the use of poisoned grain and poisoned alfalfa the smaller species are easily killed, at an average cost, including necessary labor, of about 4 cents per acre, or $25 a section. The wheat or barley crop on a section of land in the State of Washington, where the Townsend ground squirrel is abundant, is worth on an average $15 an acre, or $9,600 a section. In badly infested areas the squirrels destroy 10 per cent of the crop, worth $960. By the expenditure of $25 the owner of the section can save $935 the first year and $960 annually for the three or four succeeding years, or until the animals again become abundant.

The cost of destroying the larger species is considerably greater, but, allowing for the difference in expense, the saving on grain would scarcely fall below $800 a section.

On range lands, however, the case is very different, and the economy of destroying the squirrels is doubtful. It has been estimated that 500 of the smaller ground squirrels consume as much grass as a horse or cow. Allowing 10 squirrels to the acre, their destruction would permit the pasturage of an additional horse or cow to each 50 acres. The detriment to the range by squirrels, when abundant, is about 20 per cent of the sustaining capacity. Placing the average rental of the range at 5 cents an acre for the season, the loss amounts to 1 cent an acre. As the destruction of squirrels costs 4 cents an acre, it would require four seasons of freedom from the pests to recover the outlay. Unless, therefore, the work were undertaken on a large scale, by cooperation, so as to secure lasting results, the investment would not pay. However, since range and waste lands are the source from which cultivated fields are restocked with rodent pests, it would undoubtedly pay to destroy the squirrels on ranges adjacent to cultivated crops.

Pocket gophers.—Pocket gophers are distributed over about 1,800,000 square miles of territory in the United States, chiefly from the eastern part of the Mississippi Valley westward. Of this area about one-tenth is in farm crops, from which are derived returns of about $1,500,000,000 yearly. It is estimated that the losses caused by pocket gophers amount to $12,625,000 a year, as follows:

Loss on alfalfa	$4,000,000
Loss on native hay	2,500,000
Loss on clover and tame grasses	3,000,000
Loss on orchard and other trees	1,750,000
Loss on gardens and crops not included above	575,000
Damage to machinery and embankments	800,000
Total loss	12,625,000

Permanent crops, rather than annual ones, are most subject to injury from gophers, and the damage to corn and small grains is comparatively slight. Gophers devour potatoes, sweet potatoes, melons and cotton, but the chief damage they do is to the hay crop and fruit trees. Their favorite food is alfalfa and clover, which they destroy in two ways—by devouring and by burying. The mounds of earth thrown up in meadows cause heavy losses by covering up the grass and preventing close mowing. Where gopher mounds are abundant, from 10 to 20 per cent of the hay is lost.

The alfalfa growers of the Middle West outside of irrigation districts are the most serious losers from pocket gophers. Statistics of the acreage in alfalfa in most of the States are lacking, but two States, Kansas and Nebraska, will serve for illustration. In 1907 Nebraska had 455,792 acres of alfalfa, producing 1,450,759 tons of hay, which at $5 a ton was worth $7,253,795; Kansas had 743,050 acres of alfalfa, which at the same yield and price was worth $11,800,000. It is estimated that in Kansas pocket gophers compelled farmers to leave 10 per cent of their crop on the ground, and conditions in Nebraska were about the same. It is safe to conclude, therefore, that the loss from gophers in these two States in 1907 amounted to at least $2,000,000.

Throughout the greater part of the upper Mississippi Valley and the whole of the Missouri Valley clover, timothy, and native meadows are infested with gophers, whose mounds cause an average loss of 4 per cent of the hay crop, or a total of over $5,000,000 yearly.

The cost of destroying pocket gophers by poisons is not great. A 40-acre field of clover or alfalfa can be cleared of them at an expenditure of less than $5. Trapping is an excellent though slower method, requiring less outlay aside from labor. The feasibility of destroying gophers has been repeatedly proved, but cooperation over large areas is necessary to secure permanent results.

Field mice.—Short-tailed field mice are generally distributed throughout the grassy and mountainous parts of the United States. Under normal conditions they are among the commonest of rodents and cause losses to agricultural crops and fruit trees exceeding $3,000,000 annually.

In the Old World mouse plagues, differing in intensity, have often occurred and have resulted in widespread destruction. The most recent irruption was in France in 1904, where a considerable part of the loss of $40,000,000 attributed to rats and field mice was due to the latter animals. Until recently no plagues of similar severity have occurred in the United States, but in 1907 field mice increased enormously in various parts of the great basin region, especially in Humboldt Valley, Nevada, where over a considerable area they reached a total of 8,000 to 12,000 per acre. As a consequence 15,000 acres of alfalfa out of the 20,000 in the valley were a total loss, so that the fields had to be plowed and resown. The loss of hay, pasturage, root crops, trees, and the wheat crop for 1908, and the cost of replanting the alfalfa fields amounted to about $20 per acre, or a total for the valley of $300,000.

When the numerous irrigation schemes now on foot are completed, a very large additional acreage will be placed under alfalfa, and unless due precautions are taken a repetition of the Nevada mouse plague is almost certain, since extensive fields of alfalfa, offering the mice shelter as well as sustenance, furnish ideal conditions for their excessive multiplication.

Field experiments by the Biological Survey show that meadow mice are among the easiest mammals to control by poisoning. Under the most favorable conditions two or three years are necessary for them to increase to an actual plague, and during this time they can be effectually destroyed at a cost varying from 10 to 20 cents per acre, according to the degree of infestation; while 40 cents per acre is estimated to be the average cost of destruction after they have become a plague. Thus from a purely economic standpoint it is much cheaper to attack them whenever they show an increase than to wait until they have become excessively abundant. On alfalfa lands yielding gross returns of $50 per acre, the damage done by field mice under normal conditions of abundance amounts to $1 to $2 per acre. Almost the whole of this loss can be prevented at a cost of from 10 to 20 cents per acre, thus saving annually from 90 cents to $1.80 per acre.

Even this expenditure, small as it is, would be unnecessary providing due regard had been paid to the protection of such birds as hawks, owls, gulls, and herons, and of such mammals as foxes, coyotes, badgers, weasels, and skunks—nature's own agents in checking the abnormal increase of small rodents. The Nevada outbreak of mice was the signal for the assembling of mouse-eating birds and mammals in numbers quite sufficient, after the mice had been reduced to something like their normal number, not only to hold them in check but to reduce their numbers far below the normal. It is practically certain that the Nevada plague would never have occurred had not predaceous birds and mammals been so reduced as to be quite inadequate for the service they are always eager to perform. Predatory birds and the smaller predatory mammals are an important part of the national assets, and can not be wantonly destroyed without incurring serious consequences.

House rats and mice.—The most destructive mammalian pests in the United States are the European house rats and mice. They were introduced into America so long ago that they are thoroughly acclimatized and range over nearly the whole cultivated parts of our territory, though much more abundant and destructive in towns and cities than in the country.

Every rat in the course of a year destroys property probably worth from 50 cents to a dollar. From investigations in Washington and Baltimore during the past year it is estimated that the annual losses from rats and mice to merchants and manufacturers in cities having a population of 100,000 or more, amount to $20,000,000. The losses from the destruction of grain, poultry, eggs, and other produce on farms, in villages, and in private residences throughout the country amount to a still larger sum. Injury to buildings, furniture, and fixtures, and the cost of fighting the pest by traps, poisons, dogs, cats, ferrets, and professional rat catchers add materially to the above totals. In the absence of accurate statistics for the United States, estimates of the damage done in other countries are of interest. In Denmark the annual loss from rats is put at $3,000,000; in Great Britain from $25,000,000 to $50,000,000, and in France, in 1904, the loss from rats and field mice was estimated at $40,000,000. These figures are suggestive, in view of the fact that the United States, not including Alaska, has 35 times the area of Great Britain, 15 times the area of France, and 200 times that of Denmark.

The importance of killing rats is greatly increased by the fact that these animals are known to be carriers of vermin and disseminators of bubonic plague and other diseases. In Athens, Odessa, Oporto, Glasgow, and other European cities, and recently in San Francisco, Cal., rats have been sufficiently reduced in number to permit eradication of the plague. In San Francisco and its immediate vicinity, between May, 1907, and February, 1908, 77 deaths from plague occurred, and in the plague-prevention work carried on under supervision of the United States Marine-Hospital Service during the year beginning September 25, 1907, more than 300,000 rats have been captured, and it is estimated that nearly twice as many have been killed by poison.

Present methods of destroying rats are imperfect, and the expense is much greater than it should be. But even the crude methods of the past have saved a substantial amount to the country, and by cooperation and persistence the present improved means of destruction can be made to yield far better results than have yet been attained.

The amount spent in the United States in destroying rats is not known. In Stockholm, Sweden, from 1901–1906, inclusive, 639,515 rats were killed by the municipality at an expense in premiums of $8,570, or about 1⅓ cents per rat. Adding the expense of administration, the actual cost was less than 2 cents per rat. In the United States—as, for instance, in San Francisco—an extensive campaign against rats costs much more, yet it pays financially. But rats are such a menace to the public health that apart from pecuniary considerations they should be destroyed as completely as possible, and the war against them must be continuous to effect a permanent reduction in their numbers.

ESTIMATES OF LOSSES FROM RODENTS.

As in the case of carnivorous mammals, the following estimates are based on damages done in certain areas:

I.—*Losses due to European rats and house mice (including the brown rat, the house mouse, and the roof rat).*

Damage to grains while growing, in shock, stack, bin, crib, etc., up to December 1 each year (1 per cent of value)	$21,079,000
Damage to grains kept on the farm after December 1 for feed, seed, increase of price, etc. (1 per cent)	11,692,500
Damage to grains held in elevators, mills, warehouses, and in transportation on cars, ships, etc. (2½ per cent)	4,282,500
Damage to grain fed (largely in cities) to horses, hogs, poultry, etc., and entirely outside of farms and ranches	3,763,000
Damage to merchandise other than grains—dry goods, furs, meats, vegetables in stores and markets	10,000,000

Loss on young poultry, eggs, marketed (1 per cent of value, census of 1900)		$4,100,000
Fire losses due to rats and mice (one-fifteenth of $15,000,000)[a]		1,000,000
Total loss from European rats and house mice		$55,917,000

II.—*Losses due to other rodents.*

1. Pocket gophers:		
Damage to alfalfa	$4,000,000	
Damage to native hay	2,500,000	
Damage to clover and tame grass	3,000,000	
Damage to orchard and other trees	1,750,000	
Damage to gardens and crops not included above	575,000	
Damage to mowing machinery	800,000	
		$12,625,000
2. Ground squirrels (*citellus*), annual loss		10,000,000
3. Rabbits:		
Loss to nurseries	$1,200,000	
Loss to orchards	3,600,000	
Loss to forests, gardens, melons, etc	800,000	
Loss to pastures, stacks	400,000	
		6,000,000
4. Prairie dogs (*Cynomys*):		
Damage to pastures	1,500,000	
Damage to grain, forage, and other crops	1,000,000	
		2,500,000
5. Meadow mice:		
Damage to trees	1,800,000	
Damage to grain, alfalfa, hay, etc	1,250,000	
Damage to melons, gardens, etc	250,000	
		3,300,000
6. Woodchucks (damage to clover and hay and to haying machinery)		800,000
7. Cotton rats (*Sigmodon*)		800,000
8. Muskrats (damage to canals, embankments, etc.)		700,000
9. Other native rodents (wood rats, kangaroo rats, white-footed mice, and others)		1,250,000
Annual losses from native rodents		$37,975,000
Annual losses from European rats and mice		55,917,000
Total annual losses from rodents		$93,892,000
Annual cost of fighting rodent pests (traps, poisons, fumigators, bounties, labor)		3,000,000
Total		$96,892,000

[a] The underwriters place the losses due to defective wiring for electric lighting at $15,000,000 per annum, a large part of which they attribute to gnawing of the wires by rats and mice.

LOSSES TO LIVE STOCK BY DISEASE.

By V. H. Olmsted,
Chief of Bureau of Statistics, U. S. Department of Agriculture.

In compliance with the request of the commission, the following statements are submitted of the estimated percentages of loss to live stock from disease for a number of years, each year ending March 31. The figures have been reduced to five-year and three-year averages.

Estimated percentage of loss from disease for the year ending

HORSES.

State or Territory.	1908.	1907.	1906.	Three-year average.	1905.	1904.	1903.	1902.	1901.	Five-year average.	1900.
Maine	1.7	1.2	1.0	1.3	1.7	1.1	2.2	1.5	1.6	1.6	1.3
New Hampshire	1.4	1.6	1.6	1.5	1.5	1.4	2.0	2.1	1.9	1.8	1.5
Vermont	1.3	1.5	1.4	1.4	1.5	1.4	1.4	1.8	1.8	1.6	1.5
Massachusetts	2.2	1.5	1.3	1.7	1.6	1.6	1.8	1.8	1.1	1.6	1.6
Rhode Island	2.5	1.3	1.1	1.6	1.2	2.3	2.4	2.0	1.8	1.9	1.4
Connecticut	2.0	1.8	1.8	1.9	2.8	2.2	3.6	1.9	1.8	2.5	1.8
New York	2.2	1.8	1.5	1.8	1.7	1.8	1.7	1.9	2.1	1.8	2.1
New Jersey	1.7	1.5	1.7	1.6	1.7	2.3	1.9	1.7	2.1	1.9	2.0
Pennsylvania	1.7	1.7	1.5	1.6	1.8	1.9	2.3	1.7	1.5	1.8	1.7
Delaware	1.7	1.9	1.8	1.8	3.7	1.8	2.5	2.9	3.8	2.9	2.8
Maryland	1.4	1.5	1.9	1.6	1.7	1.7	2.1	2.3	2.6	2.1	1.8
Virginia	1.8	1.7	1.6	1.7	1.8	2.0	1.7	2.0	1.8	1.9	2.1
West Virginia	1.1	1.6	1.5	1.4	1.7	1.7	1.4	1.4	1.6	1.6	1.8
North Carolina	2.0	1.9	1.8	1.9	2.0	2.2	2.0	2.2	1.7	2.0	2.0
South Carolina	2.2	2.0	2.0	2.1	3.0	3.6	3.0	3.1	2.5	3.0	2.8
Georgia	2.0	2.0	2.1	2.0	2.5	3.5	3.3	3.8	2.3	3.1	3.3
Florida	3.0	3.1	3.0	3.0	2.9	4.3	2.9	3.2	3.5	3.4	4.2
Ohio	1.4	1.6	1.8	1.6	1.2	1.5	1.2	1.4	1.4	1.3	1.2
Indiana	1.8	1.7	1.5	1.7	1.5	1.9	1.7	1.7	1.5	1.7	1.7
Illinois	1.4	1.4	1.6	1.5	1.6	1.5	2.0	1.8	1.7	1.7	2.1
Michigan	1.6	1.8	1.6	1.7	1.6	1.8	1.6	1.9	1.7	1.7	1.5
Wisconsin	1.4	1.8	1.5	1.6	1.7	1.7	1.4	1.7	1.4	1.6	1.6
Minnesota	1.8	2.0	1.7	1.8	2.0	2.0	2.0	2.2	2.4	2.1	1.8
Iowa	1.7	1.8	1.3	1.6	1.4	1.5	1.6	1.6	1.7	1.6	1.2
Missouri	1.3	1.5	1.6	1.5	1.7	1.8	2.0	2.4	1.5	1.9	1.7
North Dakota	1.9	2.2	1.5	1.9	1.4	2.4	2.1	1.7	1.8	1.9	1.3
South Dakota	1.5	1.8	1.6	1.6	1.4	1.6	1.6	1.4	1.4	1.5	1.3
Nebraska	1.8	1.9	1.8	1.8	1.5	1.6	2.3	2.7	1.7	2.0	1.5
Kansas	1.1	1.3	1.5	1.3	1.2	1.3	1.2	1.5	1.3	1.3	1.3
Kentucky	1.9	2.0	2.0	2.0	2.0	1.8	2.1	2.6	2.0	2.1	2.3
Tennessee	1.8	2.0	1.8	1.9	2.0	1.9	2.9	2.7	2.1	2.3	3.1
Alabama	2.0	2.3	2.5	2.3	2.4	2.5	3.3	2.8	3.0	2.8	2.6
Mississippi	2.5	2.5	2.8	2.6	2.4	2.8	2.7	3.1	2.7	2.7	2.6
Louisiana	3.2	2.4	3.5	3.0	3.5	3.1	3.3	2.7	3.0	3.1	3.9
Texas	1.9	2.7	2.3	2.3	2.7	2.6	2.1	2.9	2.1	2.5	2.2
Indian Territory	.....	3.3	2.8	[b] 3.0	2.0	3.0	3.4	1.6	2.6	2.5	.....
Oklahoma	2.0	2.8	1.9	2.2	1.9	1.7	1.3	2.0	2.3	1.8	1.6
Arkansas	2.4	2.2	2.6	2.4	2.1	2.8	2.9	2.6	2.3	2.5	2.3
Montana	1.5	2.2	2.0	1.9	1.6	1.7	1.4	1.4	1.6	1.5	1.8
Wyoming	1.3	2.3	1.4	1.7	3.0	1.8	2.6	2.3	1.2	2.2	1.4
Colorado	1.4	2.3	2.2	2.0	1.9	1.9	2.4	1.9	1.6	1.9	1.7
New Mexico	2.5	3.1	2.5	2.7	3.6	2.7	4.5	2.1	3.1	3.2	1.7
Arizona	1.5	2.8	4.0	2.8	1.7	10.3	3.0	1.6	3.0	3.9	1.5
Utah	2.5	2.0	2.4	2.3	2.1	1.6	1.0	1.0	1.6	1.5	1.8
Nevada	1.6	1.0	2.0	1.5	1.5	4.8	2.4	3.1	2.4	2.8	2.7
Idaho	1.5	1.7	1.7	1.6	2.0	1.7	2.5	1.9	1.5	1.9	1.5
Washington	1.9	2.2	1.7	1.9	2.2	2.2	1.9	2.3	1.8	2.1	2.2
Oregon	2.0	1.2	1.7	1.6	1.7	1.8	2.2	1.4	1.9	1.8	1.5
California	2.0	2.2	1.8	3.0	1.6	2.0	2.1	1.6	1.4	1.7	2.1
United States	1.7	1.9	1.8	1.8	1.8	2.0	2.0	2.0	1.8	1.9	1.8

[a] Four years.

March 31, and the average for each period indicated.

HORSES.

1899.	1898.	1897.	1896.	Five-year average.	1895.	1894.	1893.	1892.	1891.	Five-year average.	1890.	1889.	1888.	Three-year average.
1.5	1.5	1.2	1.5	1.4	1.0	1.8	1.7	1.1	1.7	1.5	1.3	1.0	1.2	1.2
1.2	1.6	1.7	1.3	1.5	1.7	1.6	1.7	1.4	1.5	1.6	1.3	1.7	1.5	1.5
2.0	1.5	1.6	1.7	1.7	1.5	1.7	1.6	1.5	1.2	1.5	1.3	1.0	1.1	1.1
1.8	1.5	1.6	1.2	1.5	1.3	1.4	2.2	1.7	1.6	1.6	1.3	1.2	1.0	1.2
1.9	1.8	1.4	1.1	1.5	2.4	1.4	1.5	1.2	1.2	1.5	1.0	1.1	.7	.9
1.5	1.3	1.4	1.6	1.5	2.0	2.6	2.0	1.4	1.2	1.8	1.2	1.6	1.0	1.3
3.0	2.1	2.1	2.6	2.4	1.9	2.2	1.9	1.5	1.4	1.8	1.5	1.7	1.5	1.6
2.1	2.6	1.9	2.7	2.3	1.0	2.6	1.1	1.8	1.5	1.6	1.4	1.3	1.6	1.4
2.2	1.4	1.6	2.0	1.8	1.4	2.0	1.8	1.4	1.6	1.6	1.3	1.4	1.6	1.4
2.5	2.4	2.0	2.4	2.4	......	3.6	2.3	1.7	2.0	a 2.4	1.8	1.5	1.6	1.6
2.4	2.0	2.1	2.1	2.1	2.4	2.3	2.1	1.8	1.5	2.0	1.4	1.3	1.6	1.4
2.0	2.5	1.9	2.2	2.1	2.0	2.1	1.7	1.8	1.2	1.8	1.3	1.5	1.6	1.5
2.2	1.8	1.7	1.9	1.9	2.9	2.0	1.6	1.0	1.3	1.8	1.2	1.5	1.3	1.3
2.4	2.2	2.1	1.8	2.1	1.7	1.8	1.6	1.8	1.9	1.8	1.5	1.5	1.5	1.5
2.9	2.8	3.2	3.4	3.0	1.8	1.8	2.3	1.7	1.8	1.9	1.7	1.4	1.7	1.6
2.7	2.5	3.1	3.1	2.9	2.3	2.0	2.0	1.9	1.9	2.0	1.8	1.5	2.0	1.8
4.1	4.6	3.1	3.6	3.9	5.0	3.2	2.2	2.0	2.0	2.9	1.8	2.5	2.5	2.3
1.4	1.8	1.8	1.9	1.6	2.0	1.6	1.3	1.3	1.5	1.5	1.3	1.1	1.7	1.4
1.9	1.8	1.9	1.9	1.8	2.3	2.1	1.4	1.4	1.7	1.8	1.5	1.5	1.7	1.6
3.0	1.9	1.7	2.1	2.2	2.3	2.1	1.9	1.5	1.6	1.9	1.7	1.0	1.8	1.5
1.7	1.5	1.8	2.0	1.7	1.9	1.5	1.1	1.2	1.4	1.4	1.3	1.3	1.8	1.5
1.8	1.5	1.3	1.6	1.6	1.7	2.4	1.9	1.3	1.7	1.8	1.4	1.5	1.9	1.6
1.5	1.7	1.6	1.6	1.6	2.0	2.3	1.7	1.5	1.5	1.8	1.2	1.4	1.5	1.4
1.5	2.1	1.8	1.9	1.7	2.0	1.8	1.7	1.6	1.8	1.8	1.5	1.6	1.8	1.6
1.7	1.8	1.8	1.8	1.8	2.7	1.5	1.3	1.4	1.8	1.7	1.6	1.5	1.8	1.6
1.6	1.6	2.2	1.8	1.7	1.0	1.6	1.0	1.8	......	a 1.4	1.4	1.3	1.8	1.5
1.8	1.7	2.1	1.5	1.7	2.8	1.6	1.3	1.3	......	a 1.8	1.4	1.3	1.8	1.5
2.1	1.6	2.3	1.5	1.8	2.2	2.0	1.7	1.6	2.5	2.0	2.0	1.3	1.9	1.7
2.2	1.5	2.6	1.4	1.8	1.7	1.3	1.7	1.5	1.6	1.6	1.5	1.2	1.7	1.5
2.8	2.1	2.6	2.4	2.4	2.3	2.7	2.0	1.4	1.5	2.0	1.7	1.6	1.8	1.7
2.5	2.9	2.1	2.4	2.6	2.7	2.4	1.6	1.5	1.8	2.0	1.5	1.4	2.0	1.6
2.7	2.6	2.9	3.1	2.8	3.0	2.7	1.9	2.1	2.2	2.4	1.7	2.0	2.2	2.0
3.4	3.2	5.2	3.5	3.6	4.1	3.1	2.6	2.3	2.0	2.8	1.8	1.6	2.1	1.8
6.2	4.7	5.0	3.3	4.6	4.4	3.8	3.7	2.2	2.3	3.3	2.0	1.7	2.7	2.1
3.2	2.6	2.4	2.5	2.6	3.1	2.8	1.7	1.8	1.4	2.2	1.5	2.0	2.4	2.0
2.4	2.5	1.6	3.0	2.2	1.4	2.5	......	......	......	b 2.0	......	......	......	......
3.2	1.9	2.1	2.8	2.5	3.6	2.5	2.5	2.0	2.5	2.6	1.8	2.2	2.5	2.2
3.9	1.5	1.8	2.3	2.3	1.8	2.5	2.0	1.8	1.5	1.9	3.5	1.5	2.5	2.5
1.3	1.5	2.0	1.6	1.6	2.4	1.8	1.4	1.5	1.6	1.7	3.0	1.2	......	b 2.1
1.8	2.4	1.7	1.4	1.8	1.1	1.6	1.3	1.9	1.5	1.5	3.0	1.4	1.5	2.0
2.4	1.4	2.0	2.7	2.0	1.3	2.2	.4	2.0	2.1	1.6	1.5	3.7	3.0	2.7
.8	1.0	1.4	1.0	1.1	1.6	3.2	1.0	1.8	1.0	1.7	1.3	1.2	2.7	1.7
2.2	2.5	2.1	1.2	2.0	4.0	2.2	2.6	1.9	1.9	2.5	2.5	1.2	2.5	2.1
4.7	3.8	.9	1.6	2.7	1.0	4.1	2.2	2.0	1.8	2.2	3.5	2.8	1.1	2.5
1.8	2.2	3.5	1.7	2.1	2.5	3.1	3.5	1.5	1.6	2.4	3.3	1.2	1.6	2.0
2.2	1.6	3.9	2.0	2.4	3.8	1.1	.5	1.2	1.7	1.7	3.0	1.2	1.4	1.9
3.3	1.9	4.0	2.2	2.6	1.5	3.2	1.0	1.3	1.8	1.8	2.5	1.1	2.2	1.9
3.4	2.5	2.3	1.9	2.4	2.5	3.1	2.4	1.5	1.9	2.3	2.0	1.2	2.3	1.8
2.3	2.0	2.1	2.0	2.0	2.2	2.1	1.7	1.5	1.7	1.8	1.6	1.5	1.8	1.6

b Two years.

Estimated percentage of loss from disease for the year ending

CATTLE.

State or Territory.	1908.	1907.	1906.	Three-year average.	1905.	1904.	1903.	1902.	1901.	Five-year average.	1900.	1899.	1898.
Maine	1.5	1.4	1.0	1.3	1.2	0.8	1.2	1.0	1.2	1.1	1.2	1.5	1.0
New Hampshire	1.4	2.1	1.8	1.8	1.6	1.4	2.0	2.2	1.6	1.8	1.8	1.8	1.4
Vermont	1.3	1.8	1.5	1.5	1.5	2.9	2.5	1.4	2.3	2.1	1.7	2.2	1.5
Massachusetts	2.1	1.8	1.4	1.8	1.5	1.9	3.0	2.0	1.7	2.0	1.9	1.9	1.9
Rhode Island	2.2	1.6	1.5	1.8	1.3	2.1	2.6	1.9	2.0	2.0	1.8	1.8	2.0
Connecticut	1.8	1.5	1.6	1.6	1.7	1.8	1.5	2.0	1.6	1.7	1.5	1.9	1.2
New York	2.2	2.1	1.6	2.0	1.9	1.9	2.0	2.0	1.9	1.9	2.4	2.1	2.3
New Jersey	2.0	2.1	2.0	2.0	2.3	2.3	2.7	1.7	2.3	2.3	2.2	3.3	2.5
Pennsylvania	1.8	1.8	1.5	1.7	1.7	2.0	2.0	1.9	1.7	1.9	2.1	2.2	1.8
Delaware	1.2	1.8	2.1	1.7	4.1	2.9	2.2	1.6	1.3	2.4	2.5	2.3	2.3
Maryland	1.2	1.2	1.3	1.2	1.4	1.3	1.8	2.0	1.9	1.7	1.7	1.5	1.4
Virginia	2.0	2.0	1.8	1.9	1.8	2.1	2.0	2.0	1.8	1.9	1.9	2.1	2.5
West Virginia	1.5	2.1	1.5	1.7	1.8	1.8	2.1	1.5	1.8	1.8	2.0	2.3	1.5
North Carolina	2.2	2.0	1.8	2.0	2.1	2.3	1.8	1.9	1.8	2.0	2.1	2.0	2.3
South Carolina	2.6	2.1	2.2	2.3	2.7	2.9	2.8	2.3	2.4	2.6	2.3	2.5	2.5
Georgia	2.3	2.2	2.0	2.2	2.0	3.1	3.3	2.4	2.2	2.6	2.2	1.9	3.7
Florida	3.8	3.6	3.5	3.6	3.7	4.2	2.8	3.8	3.2	3.5	3.5	3.1	4.5
Ohio	1.4	1.5	1.6	1.5	1.3	1.4	1.2	1.2	1.2	1.3	1.2	1.3	1.5
Indiana	1.6	1.7	1.5	1.6	1.5	1.8	1.5	1.6	1.4	1.6	1.5	1.8	1.4
Illinois	1.5	1.8	1.8	1.7	1.5	1.6	2.0	1.8	1.4	1.7	1.6	2.1	1.6
Michigan	1.5	1.6	1.3	1.5	1.5	1.5	1.8	1.6	1.4	1.6	1.5	1.4	1.2
Wisconsin	1.8	1.8	1.7	1.8	1.7	1.5	1.4	1.6	1.5	1.5	1.3	1.4	1.2
Minnesota	1.8	1.9	1.7	1.8	1.7	2.1	2.0	1.6	1.9	1.9	1.4	1.2	1.7
Iowa	1.7	1.7	1.5	1.6	1.7	2.0	2.1	2.2	2.0	2.0	3.0	2.0	1.7
Missouri	1.5	1.6	2.1	1.7	2.4	2.5	2.6	2.1	1.8	2.3	1.9	1.5	1.5
North Dakota	1.5	1.8	1.7	1.7	1.8	3.4	2.5	1.5	1.5	2.1	1.7	1.1	2.0
South Dakota	2.0	2.3	1.7	2.0	2.1	2.2	2.1	2.1	4.4	2.6	1.6	1.8	1.4
Nebraska	2.1	2.7	2.5	2.4	2.3	2.6	3.6	3.4	2.9	3.0	2.0	2.2	2.3
Kansas	1.2	1.6	1.5	1.4	1.5	1.8	1.9	2.1	1.9	1.8	1.9	1.7	2.1
Kentucky	2.1	1.9	2.1	2.0	2.3	2.0	2.3	2.9	1.9	2.3	2.1	1.9	1.6
Tennessee	2.1	2.3	2.1	2.2	2.6	2.7	3.0	3.2	2.2	2.7	2.8	3.0	3.2
Alabama	2.5	2.5	3.1	2.7	2.8	2.9	2.9	2.6	2.4	2.7	2.2	2.4	2.1
Mississippi	2.7	2.6	3.2	2.8	2.9	3.0	2.7	2.0	3.8	2.9	2.3	3.1	3.8
Louisiana	3.0	2.6	4.0	3.2	4.9	3.1	5.0	3.1	2.7	3.8	3.1	4.7	3.2
Texas	2.0	2.0	2.5	2.2	2.7	3.2	3.0	2.3	3.0	2.8	2.3	2.2	2.2
Indian Territory	......	2.9	3.0	[b] 2.0	3.2	2.5	3.0	3.0	4.2	3.2	......	......	......
Oklahoma	2.1	2.1	2.1	2.1	2.0	2.5	2.2	2.1	1.9	2.1	1.2	4.5	2.6
Arkansas	3.0	3.0	4.0	3.3	3.5	3.6	3.2	2.7	2.7	3.1	2.9	3.6	1.8
Montana	2.1	2.4	2.4	2.3	1.8	1.7	1.7	1.0	1.8	1.6	1.7	1.5	1.6
Wyoming	2.2	1.9	1.4	1.8	1.3	3.0	2.1	3.1	1.8	2.3	1.1	.9	2.5
Colorado	1.5	1.9	2.3	1.9	1.9	2.4	2.9	2.4	2.5	2.4	2.6	2.1	1.5
New Mexico	3.0	2.0	1.5	2.2	1.8	2.6	4.0	1.5	2.8	2.5	1.8	3.0	.8
Arizona	2.5	1.8	2.3	2.2	1.5	4.7	2.8	1.2	4.9	3.0	1.9	2.8	1.0
Utah	2.0	1.9	1.8	1.9	2.2	1.4	1.4	1.7	1.6	1.7	1.8	2.5	2.1
Nevada	1.5	2.0	3.0	2.2	2.5	3.8	2.7	1.9	1.9	2.6	1.7	1.4	2.9
Idaho	1.4	2.0	2.0	1.8	1.9	1.8	1.4	1.5	1.0	1.5	1.7	.9	1.5
Washington	1.7	2.0	1.2	1.6	1.7	1.7	1.7	1.8	1.4	1.7	1.8	1.1	1.1
Oregon	1.5	1.3	1.7	1.5	1.4	1.6	1.5	2.0	1.5	1.6	1.2	3.2	1.4
California	2.5	2.8	2.6	2.6	2.6	3.3	2.9	2.4	2.0	2.6	1.6	2.9	3.7
United States	1.9	2.0	2.0	2.0	2.1	2.4	2.4	2.1	2.2	2.2	2.0	2.0	2.0

[a] Four years.

March 31, and the average for each period indicated—Continued.

CATTLE.

1897.	1896.	Five-year average.	1895.	1894.	1893.	1892.	1891.	Five-year average.	1890.	1889.	1888.	1887.	1886.	Five-year average.
2.0	0.6	1.3	1.5	2.2	0.6	1.1	1.7	1.4	1.0	1.3	1.3	2.0	2.0	1.5
2.9	.7	1.7	2.1	2.0	.4	1.1	1.4	1.4	.9	1.1	1.6	2.5	2.0	1.6
2.5	1.0	1.8	1.6	3.2	1.4	1.2	1.1	1.7	.6	1.2	1.5	2.0	2.0	1.5
3.1	3.3	2.4	1.8	.9	1.7	1.1	1.3	1.4	.8	1.0	1.5	2.0	2.0	1.5
1.8	2.9	2.1	3.2	2.1	1.6	1.5	1.2	1.9	.8	1.0	1.2	2.0	2.0	1.4
1.9	1.9	1.7	1.9	2.7	1.2	1.8	1.5	1.8	1.3	1.8	1.3	2.0	2.0	1.7
2.2	2.2	2.2	2.4	2.5	2.6	1.5	1.7	2.1	1.6	2.0	2.2	2.5	2.0	2.1
1.6	2.2	2.4	1.8	3.0	1.1	1.3	1.9	1.8	1.7	1.9	.9	2.0	2.0	1.7
1.8	1.7	1.9	1.9	1.8	1.6	1.5	1.5	1.7	1.7	1.3	1.9	3.0	2.0	2.0
3.4	3.6	2.8	......	1.0	1.2	2.0	1.1	[a] 1.3	2.4	1.2	2.3	3.0	4.0	2.6
2.1	2.6	1.9	2.5	1.8	2.0	1.5	1.3	1.8	1.7	1.8	2.0	4.0	3.0	2.5
2.1	2.3	2.2	1.5	1.5	1.8	1.5	1.6	1.6	1.8	1.9	2.4	4.0	4.0	2.8
1.7	1.5	1.8	2.1	1.4	1.4	.5	.8	1.2	.7	2.0	2.0	3.0	3.0	2.1
1.8	1.9	2.0	2.4	1.7	1.6	2.3	2.1	2.0	2.2	2.2	2.9	6.0	6.0	3.9
2.1	2.6	2.4	2.0	1.4	2.2	1.5	2.4	1.9	2.3	2.1	2.8	6.0	6.0	3.8
2.5	2.2	2.5	2.8	3.1	2.2	1.8	2.3	2.4	1.3	3.4	3.0	7.0	7.0	4.3
2.6	2.7	3.3	2.1	4.3	1.7	3.0	3.5	2.9	3.5	5.5	3.5	7.0	8.0	5.5
1.4	1.2	1.3	1.2	1.3	1.4	.9	1.1	1.2	.8	1.5	1.8	3.0	2.0	1.8
1.7	1.5	1.6	2.5	1.1	1.8	1.2	1.2	1.6	.7	2.0	1.6	4.0	2.0	2.1
1.6	1.7	1.7	2.7	1.6	1.3	1.3	1.2	1.6	.9	1.9	2.0	3.0	2.0	2.0
1.4	1.5	1.4	1.7	1.0	.4	1.1	1.3	1.1	1.3	1.8	1.4	3.0	2.0	1.9
1.3	1.4	1.3	1.1	1.5	1.8	1.7	1.7	1.6	1.2	1.9	2.1	2.5	2.0	1.9
1.4	1.5	1.4	1.7	1.4	1.3	1.0	1.7	1.4	1.4	2.0	2.2	2.0	2.0	1.9
2.2	1.9	2.2	2.0	1.4	.5	1.3	2.0	1.4	1.5	1.6	2.5	3.0	2.0	2.1
1.7	1.6	1.6	1.7	1.4	.9	.8	1.6	1.3	1.2	2.0	2.7	3.0	3.0	2.4
1.7	2.1	1.7	1.7	1.0	1.0	.5	1.2	1.1	.8	2.0	3.4	4.0	3.0	2.6
2.3	1.8	1.8	2.4	1.2	1.5	.4	1.2	1.3	.8	2.0	3.4	4.0	3.0	2.6
2.0	1.8	2.1	1.8	1.4	2.1	.5	2.5	1.7	2.0	2.2	3.5	3.0	3.0	2.7
1.9	2.1	1.9	1.4	1.6	1.5	.5	1.8	1.4	1.8	1.8	2.3	4.0	3.0	2.6
1.9	1.8	1.9	1.7	1.8	1.8	.7	.8	1.4	.7	1.8	2.5	3.0	2.0	2.0
2.6	2.1	2.7	2.1	2.4	1.0	.7	1.2	1.5	1.4	1.7	2.7	5.0	6.0	3.4
2.1	2.4	2.2	2.3	2.8	2.3	1.2	.9	1.9	.9	3.0	3.7	6.0	6.0	3.9
2.8	3.0	3.0	4.3	2.1	1.6	2.0	1.3	2.3	.9	3.2	3.5	7.0	6.0	4.1
2.8	2.7	3.3	4.7	2.4	3.1	1.2	1.0	2.5	1.5	3.4	4.0	6.0	7.0	4.4
1.6	2.3	2.1	3.4	3.3	2.0	1.7	.7	2.2	.4	3.5	4.5	7.0	6.0	4.3
......	......	......	......	......	......	......	......	......	......	......	4.0	......	6.0	[b] 5.0
1.5	1.5	2.3	......	......	......	......	......	......	......	......	......	......	......	......
2.1	2.1	2.5	2.3	2.8	2.4	1.7	2.8	2.4	3.2	2.6	3.2	8.0	7.0	4.8
2.1	1.7	1.7	2.0	.9	5.0	.3	1.5	1.9	2.5	2.5	3.5	9.0	4.0	4.3
2.4	.9	1.6	1.6	.3	2.2	.2	.5	1.0	1.0	2.7	2.5	6.0	4.0	3.2
2.1	1.5	2.0	2.0	2.7	1.5	1.3	1.2	1.7	1.4	3.0	5.5	4.5	6.0	4.1
5.0	4.1	2.9	1.7	2.1	4.0	2.8	1.6	2.4	1.2	4.2	3.7	4.0	5.0	3.6
1.7	2.5	2.0	.0	......	.2	3.5	1.0	[a] 1.2	1.0	3.5	5.0	4.0	5.0	3.7
1.4	1.9	1.9	2.3	3.6	3.3	2.4	1.0	2.5	2.7	3.7	3.5	4.0	3.0	3.4
1.2	1.4	1.7	.5	1.7	.8	2.0	1.4	1.3	4.0	3.5	3.0	4.5	4.0	3.8
1.4	1.9	1.5	.6	1.4	.3	1.5	1.2	1.0	2.8	2.0	3.3	9.0	4.0	4.2
1.2	1.5	1.3	1.2	1.0	.5	.8	.5	.8	3.5	2.5	2.7	3.0	3.0	2.9
1.4	1.2	1.7	1.3	.7	.5	.8	.6	.8	3.0	2.0	2.2	5.0	4.0	3.2
1.9	2.4	2.5	2.1	1.1	1.4	1.2	2.0	1.6	3.0	2.3	4.5	4.0	4.0	3.6
1.9	2.0	2.0	2.1	1.9	1.7	1.3	1.5	1.7	1.3	2.4	2.9	4.4	4.0	3.0

[b] Two years.

Estimated percentage of loss from disease for the year ending

SHEEP.

State or Territory.	1908.	1907.	1906.	Three-year average.	1905.	1904.	1903.	1902.	1901.	Five-year average.	1900.	1899.	1898.
Maine	2.2	2.1	2.5	2.3	3.8	2.2	2.0	1.6	2.0	2.3	2.5	2.8	2.2
New Hampshire	2.2	2.5	2.4	2.4	2.0	3.7	2.7	2.8	3.7	3.0	2.7	2.2	2.7
Vermont	2.2	1.6	2.0	1.9	2.0	2.5	2.7	2.5	2.2	2.4	2.2	3.4	2.1
Massachusetts	1.9	2.2	1.5	1.9	1.4	1.0	1.4	1.6	1.6	1.4	1.2	1.3	1.4
Rhode Island	1.4	1.4	1.5	1.4	1.0	1.2	2.0	1.7	2.0	1.6	2.3	2.8	1.8
Connecticut	2.1	2.4	2.4	2.3	3.2	3.0	3.1	2.2	1.9	2.7	1.6	2.2	1.6
New York	2.9	2.3	2.0	2.4	2.7	1.7	2.5	2.5	2.5	2.4	2.6	2.6	2.8
New Jersey	2.5	2.6	2.0	2.4	2.5	1.9	3.2	2.2	2.4	2.4	2.3	1.8	4.4
Pennsylvania	2.6	3.0	2.2	2.6	2.8	2.8	2.9	2.9	2.9	2.9	3.3	3.2	1.9
Delaware	1.6	2.5	2.5	2.2	2.6	3.4	3.0	3.2	2.4	2.9	2.2	1.8	1.8
Maryland	2.6	2.5	2.5	2.5	2.6	2.2	2.9	3.1	2.5	2.7	2.5	2.5	2.9
Virginia	3.8	3.5	3.0	3.4	3.4	3.3	3.2	4.0	3.0	3.4	2.8	2.6	2.6
West Virginia	2.8	3.5	3.5	3.3	3.3	3.4	3.9	3.3	3.6	3.5	3.8	3.8	3.4
North Carolina	2.0	2.0	2.2	2.1	3.3	3.1	2.3	2.3	2.1	2.6	2.6	2.4	3.0
South Carolina	2.6	2.3	2.3	2.4	3.1	3.5	3.3	3.5	2.0	3.1	2.6	2.8	2.6
Georgia	3.0	3.2	2.5	2.9	2.9	5.1	4.9	4.7	2.2	4.0	3.6	2.7	1.9
Florida	4.0	3.2	3.0	3.4	3.2	3.2	3.2	5.1	2.5	3.4	3.5	2.7	11.5
Ohio	2.8	2.9	3.0	2.9	2.3	2.4	2.3	2.9	2.8	2.5	1.9	2.8	2.8
Indiana	3.7	3.1	3.0	3.3	2.3	3.2	3.3	2.9	3.2	3.0	3.1	3.4	2.3
Illinois	2.6	2.2	3.0	2.6	2.2	2.3	3.4	2.1	2.4	2.5	2.4	2.7	1.8
Michigan	3.0	2.8	2.6	2.8	2.6	3.5	3.4	3.2	3.6	3.3	2.9	2.5	2.5
Wisconsin	1.9	2.2	2.0	2.0	1.9	2.7	2.3	2.0	2.2	2.2	1.9	2.1	2.7
Minnesota	2.0	1.9	1.8	1.9	1.9	2.7	2.6	1.9	2.0	2.2	1.8	1.3	1.7
Iowa	2.5	2.6	2.3	2.5	2.6	2.6	3.1	2.4	3.0	2.7	3.6	3.3	2.1
Missouri	2.6	2.4	3.3	2.8	3.1	3.2	3.0	2.5	2.4	2.8	2.7	2.1	2.2
North Dakota	2.0	2.3	1.6	2.0	1.9	3.8	4.0	1.6	1.8	2.6	1.7	1.0	1.7
South Dakota	2.1	2.3	2.1	2.2	2.7	2.4	2.8	2.5	2.0	2.5	1.5	1.7	0.9
Nebraska	2.4	2.7	2.5	2.5	1.9	2.7	3.6	2.2	0.9	2.3	1.0	1.2	1.9
Kansas	1.1	1.3	1.0	1.1	1.3	1.2	1.9	1.8	1.0	1.4	1.0	1.7	1.7
Kentucky	3.5	3.0	3.0	3.2	4.0	3.5	3.3	4.1	3.3	3.6	3.6	4.2	2.6
Tennessee	2.6	2.5	2.5	2.5	3.4	3.4	3.2	3.2	2.8	3.2	3.2	3.3	4.1
Alabama	2.9	3.2	4.0	3.4	2.9	6.1	4.3	2.9	2.7	3.8	2.9	2.8	3.0
Mississippi	4.2	6.5	6.0	5.6	3.7	3.9	3.0	2.5	5.3	3.7	2.5	3.3	3.9
Louisiana	2.4	3.0	3.5	3.0	4.3	4.9	4.3	2.8	2.4	3.7	3.6	4.1	4.1
Texas	1.8	2.8	3.0	2.5	3.1	2.3	3.3	4.3	2.4	3.1	2.1	2.2	2.6
Indian Territory	1.7	1.3	2.0	1.7	1.1	3.7	3.2	2.0	1.5	2.3	....	....	....
Oklahoma	1.7	3.0	1.8	2.2	5.4	2.0	2.4	2.5	1.3	2.7	1.0	0.4	1.7
Arkansas	2.5	2.2	2.0	2.2	3.4	3.1	2.4	2.6	3.2	2.9	2.7	3.5	1.9
Montana	1.3	3.4	1.7	2.1	2.0	1.8	2.0	1.8	1.4	1.8	1.9	1.8	2.6
Wyoming	3.0	3.0	1.5	2.5	2.4	2.0	2.1	1.4	1.9	2.0	1.0	1.0	5.7
Colorado	1.9	2.0	1.8	1.9	2.5	3.2	3.0	2.8	1.5	2.6	0.9	1.8	5.1
New Mexico	2.2	1.7	1.5	1.8	2.9	2.4	5.1	3.4	4.0	3.6	1.7	1.6	1.8
Arizona	1.6	3.0	1.6	2.1	1.6	3.3	3.0	2.0	2.2	2.4	1.2	1.5	0.9
Utah	1.5	1.0	1.5	1.3	2.1	2.2	2.1	2.9	2.1	2.3	2.0	2.1	3.8
Nevada	2.5	3.0	3.0	2.8	4.4	4.8	2.0	2.4	1.6	3.0	2.7	0.6	1.6
Idaho	1.8	1.8	2.5	2.0	2.1	2.5	2.1	2.1	2.4	2.2	1.8	1.0	1.2
Washington	1.5	2.6	2.0	2.0	2.0	2.3	2.1	1.9	2.8	2.2	2.0	1.1	1.5
Oregon	1.1	1.5	2.5	1.7	1.8	2.3	2.2	1.5	2.2	2.0	1.9	3.0	1.4
California	2.5	4.0	2.6	3.0	2.2	3.0	3.3	2.1	1.6	2.4	2.8	2.5	2.2
United States	2.2	2.6	2.2	2.3	2.5	2.6	2.8	2.5	2.4	2.6	2.0	2.1	2.6

March 31, and the average for each period indicated—Continued.

SHEEP.

1897.	1896.	Five-year average.	1895.	1894.	1893.	1892.	1891.	Five-year average.	1890.	1889.	1888.	1887.	1886.	Five-year average.
2.2	1.9	2.3	2.4	3.5	2.0	2.5	2.7	2.6	2.2	2.6	3.1	5.0	4.0	3.4
3.8	1.8	2.6	3.0	4.3	1.4	2.6	2.8	2.8	2.3	2.0	3.5	4.0	4.0	3.2
2.7	0.8	2.2	3.3	2.3	1.7	2.5	2.7	2.5	2.3	2.3	3.0	4.0	4.0	3.1
3.2	3.0	2.0	14.6	1.6	1.2	1.7	1.9	4.2	2.0	1.8	3.0	4.0	4.0	3.0
2.1	5.0	2.8	2.6	3.8	0.5	1.8	2.7	2.3	2.4	1.5	2.0	4.0	3.0	2.6
4.0	2.6	2.4	4.7	2.1	1.7	2.3	2.5	2.7	1.9	2.5	2.5	4.0	4.0	3.0
3.1	3.3	2.9	4.7	2.3	2.8	2.6	2.1	2.9	1.9	2.7	3.3	4.0	4.0	3.2
2.2	2.5	2.6	2.3	4.5	2.8	2.6	2.5	2.9	1.9	1.5	1.8	5.0	3.0	2.6
2.8	3.1	2.9	6.5	1.6	5.6	1.9	2.6	3.6	1.7	3.0	3.2	4.0	3.0	3.0
4.1	6.2	3.2	......	1.4	1.9	2.0	2.0	[a] 1.8	2.5	2.0	3.0	5.0	5.0	3.5
2.9	2.7	2.7	1.9	3.4	2.0	1.9	2.7	2.4	2.4	2.2	2.1	4.0	4.0	2.9
3.4	3.3	2.9	4.5	2.5	3.3	1.9	2.3	2.9	2.1	3.5	4.1	9.0	8.0	5.3
3.1	3.9	3.6	2.6	2.9	3.6	1.0	2.5	2.5	2.3	3.6	4.0	6.0	7.0	4.6
2.8	2.8	2.7	3.0	3.0	2.2	1.5	3.3	2.6	2.8	3.7	4.6	11.0	8.0	6.0
5.5	3.3	3.4	1.7	2.8	3.2	2.0	2.5	2.4	3.1	3.6	4.1	7.0	8.0	5.2
4.7	3.5	3.3	6.2	1.0	4.4	2.7	3.6	3.6	3.0	6.0	5.0	13.0	12.0	7.8
3.2	2.9	4.8	3.8	2.8	2.2	3.6	6.5	3.8	6.5	5.9	5.5	11.0	12.0	8.2
3.8	2.4	2.7	2.7	2.3	1.8	1.5	1.5	2.0	1.7	3.3	3.5	5.0	4.0	3.5
4.1	3.3	3.2	4.1	3.0	3.8	1.9	3.3	3.2	3.0	3.2	4.7	7.0	6.0	4.8
3.3	2.7	2.6	4.3	2.0	2.1	1.6	2.5	2.5	2.2	3.0	4.4	6.0	5.0	4.1
2.9	2.5	2.7	4.2	1.9	1.9	1.3	2.8	2.4	1.9	2.6	2.4	4.0	4.0	3.0
1.9	2.8	2.3	2.3	2.6	2.8	1.4	2.4	2.3	2.0	3.5	3.7	5.0	5.0	3.8
1.7	1.8	1.7	2.8	2.0	1.6	1.0	2.6	2.0	2.6	3.0	4.0	5.0	4.0	3.7
4.9	2.5	3.3	2.7	1.7	1.1	1.1	2.2	1.8	1.2	3.5	3.2	6.5	5.0	3.9
3.1	2.9	2.6	3.2	2.0	1.0	1.4	2.7	2.1	1.5	3.9	4.0	7.0	7.0	4.7
1.9	2.3	1.7	4.0	2.1	2.0	1.8	2.4	2.5	1.0	3.2	4.2	6.0	4.0	3.7
2.5	1.6	1.6	3.0	3.2	2.8	1.6	2.4	2.6	1.0	3.2	4.2	6.0	4.0	3.7
1.3	1.9	1.5	3.1	2.1	0.8	1.3	3.1	2.1	1.8	2.8	3.5	6.0	6.0	4.0
1.3	1.6	1.5	0.9	1.7	1.2	1.1	1.8	1.3	1.7	2.6	3.5	6.0	7.0	4.2
3.8	3.6	3.6	2.9	3.1	1.5	1.2	3.0	2.3	3.0	3.8	4.3	8.0	6.0	5.0
3.1	3.2	3.4	3.8	3.5	4.2	1.8	3.2	3.3	3.0	3.8	4.9	11.0	12.0	6.9
3.7	3.6	3.2	3.6	0.3	4.1	3.5	3.7	3.0	2.9	4.5	7.0	12.0	12.0	7.7
3.1	3.8	3.3	4.2	2.4	3.4	3.2	3.7	3.4	4.5	4.6	6.0	13.0	10.0	7.6
3.6	4.1	3.9	5.2	1.4	3.7	1.9	4.0	3.2	5.7	4.7	5.0	11.0	11.0	7.5
2.1	3.5	2.5	3.3	2.2	3.4	2.3	2.0	2.6	2.2	4.2	5.5	9.0	13.0	6.8
......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
1.1	0.5	0.9	......	......	......	......	......	......	......	......	......	......	......	......
4.3	2.8	3.0	3.8	4.0	2.5	1.8	3.2	3.1	2.5	4.0	4.7	11.0	13.0	7.0
1.0	1.7	1.8	1.0	0.8	1.3	.8	2.0	1.2	2.2	3.2	4.4	11.0	4.0	5.0
0.0	3.2	2.2	1.6	2.0	0.6	.9	1.7	1.4	2.0	3.0	5.1	5.0	5.0	4.0
1.3	2.6	2.3	3.3	1.1	2.3	1.5	1.6	2.0	1.4	5.0	5.2	9.0	8.0	5.7
2.8	2.8	2.1	0.6	1.8	4.2	3.0	2.5	2.4	2.7	5.0	5.7	6.0	7.0	5.3
1.0	1.0	1.1	0.1	......	1.0	3.0	2.0	[a] 1.5	2.3	4.4	4.3	8.0	7.0	5.2
1.8	1.5	2.2	2.4	1.9	2.3	2.7	3.7	2.6	2.2	5.5	6.5	8.0	6.0	5.6
1.4	0.9	1.4	0.0	4.0	1.1	2.3	1.9	1.9	6.5	5.0	3.7	8.0	8.0	6.2
1.9	1.8	1.5	1.0	1.0	1.3	1.8	2.0	1.4	1.1	3.0	6.0	10.0	5.0	5.0
1.6	1.3	1.5	0.7	0.8	2.6	0.7	1.8	1.3	3.4	2.9	3.5	8.0	7.0	5.0
2.0	2.8	2.2	1.6	1.1	1.2	0.9	1.7	1.3	3.0	4.2	5.1	7.0	5.0	4.9
2.7	4.7	3.0	2.9	2.4	1.9	1.8	1.9	2.2	3.4	4.2	5.7	8.0	6.0	5.5
2.3	2.7	2.3	2.6	2.0	2.4	1.9	2.3	2.2	2.4	3.8	4.6	7.0	7.0	5.0

[a] Four years.

Estimated percentage of loss from disease for the year ending

SWINE.

State or Territory.	1908.	1907.	1906.	Three-year average.	1905.	1904.	1903.	1902.	1901.	Five-year average.	1900.	1899.	1898.
Maine	1.1	1.0	1.2	1.1	1.2	1.0	1.4	0.9	1.5	1.2	1.3	1.8	1.3
New Hampshire	1.5	1.4	2.0	1.6	2.2	1.5	1.2	1.9	1.4	1.6	2.0	2.0	2.4
Vermont	1.5	1.4	1.7	1.5	1.8	1.5	2.4	2.0	2.4	2.0	1.8	2.5	1.7
Massachusetts	2.2	2.5	1.8	2.2	2.0	2.3	2.5	2.1	1.6	2.1	2.2	1.9	1.6
Rhode Island	2.3	1.2	1.9	1.8	2.2	2.5	2.4	1.9	2.4	2.3	1.8	3.1	2.7
Connecticut	2.3	1.8	2.0	2.0	2.3	2.8	3.0	2.4	1.9	2.5	1.7	1.9	1.6
New York	1.8	2.1	1.9	1.9	1.7	3.3	1.8	1.9	1.9	2.1	2.0	2.4	2.5
New Jersey	2.4	2.8	2.2	2.5	2.2	3.2	3.3	2.3	2.5	2.7	2.7	4.3	4.0
Pennsylvania	2.7	2.8	2.3	2.6	2.3	2.7	3.6	3.2	2.4	2.8	2.5	3.2	3.0
Delaware	2.8	3.0	3.0	2.9	4.3	10.1	5.8	3.7	2.7	5.3	5.7	4.7	5.9
Maryland	2.9	3.0	3.5	3.1	4.3	3.1	3.2	3.3	4.7	3.7	3.7	4.2	7.1
Virginia	4.6	4.5	4.0	4.4	4.3	5.5	6.1	4.6	4.3	5.0	4.5	3.7	7.8
West Virginia	2.5	3.3	3.1	3.0	3.6	3.5	3.6	2.6	3.1	3.3	4.9	4.9	7.9
North Carolina	6.0	6.5	5.5	6.0	9.7	9.6	6.4	8.0	4.9	7.7	6.5	6.1	9.1
South Carolina	5.7	5.5	5.0	5.4	8.5	7.5	6.6	8.2	6.1	7.4	7.3	8.2	7.5
Georgia	4.4	5.0	5.5	5.0	5.1	8.9	11.8	8.9	10.3	9.0	9.4	9.0	10.8
Florida	7.3	6.8	7.5	7.2	8.2	7.2	11.3	10.4	9.1	9.2	11.8	8.5	14.9
Ohio	3.5	4.0	5.0	4.2	3.8	5.0	5.0	4.1	5.5	4.7	4.6	6.5	7.2
Indiana	5.2	5.8	6.0	5.7	5.4	7.8	7.3	4.1	5.6	6.0	6.9	11.5	7.4
Illinois	6.0	4.8	6.0	5.6	4.6	5.8	7.4	4.7	7.7	6.0	6.8	10.4	10.4
Michigan	3.0	3.1	2.2	2.8	2.5	3.7	3.0	2.9	3.6	3.1	2.9	3.9	3.3
Wisconsin	2.3	2.4	2.0	2.2	2.2	2.7	2.5	3.1	10.3	4.2	3.1	4.9	5.0
Minnesota	3.0	3.3	3.0	3.1	2.1	3.0	3.9	3.5	9.4	4.4	8.4	7.9	18.0
Iowa	6.9	5.0	4.5	5.5	4.2	5.5	5.3	4.8	8.9	5.7	7.7	17.4	17.5
Missouri	7.0	5.4	6.5	6.3	7.4	7.7	6.7	4.4	4.8	6.2	7.0	9.0	11.0
North Dakota	1.1	1.6	1.1	1.3	1.3	2.4	2.0	1.4	2.4	1.9	2.2	1.8	2.0
South Dakota	4.5	6.1	9.5	6.7	2.3	5.4	6.8	8.2	10.0	6.5	3.9	6.2	22.0
Nebraska	7.0	7.5	8.8	7.8	4.6	5.7	7.7	6.5	14.0	7.7	7.4	9.8	12.8
Kansas	4.0	3.7	3.4	3.7	3.4	3.9	3.5	3.2	5.0	3.8	6.0	6.5	7.0
Kentucky	6.2	5.2	5.5	5.6	6.3	7.1	5.9	5.9	6.7	6.4	8.1	8.5	10.0
Tennessee	5.5	5.3	4.7	5.2	7.3	7.9	6.4	6.1	9.0	7.3	9.2	9.6	9.3
Alabama	5.6	5.5	6.0	5.7	5.7	8.2	7.1	6.9	9.4	7.5	7.8	7.3	7.9
Mississippi	7.5	5.7	6.0	6.4	6.9	8.1	4.1	5.7	8.5	6.7	5.4	7.9	8.6
Louisiana	8.5	8.0	12.0	9.5	11.3	8.5	11.6	9.9	7.5	9.8	10.1	11.4	13.5
Texas	3.0	4.0	4.2	3.7	5.5	3.7	4.0	6.1	5.9	5.0	3.9	3.9	5.6
Indian Territory	......	4.3	5.5	[b] 4.9	16.0	7.8	10.3	8.1	10.5	10.5	......	......	......
Oklahoma	4.0	5.0	2.2	3.7	2.3	2.4	2.5	2.7	4.6	2.9	.5	4.7	4.8
Arkansas	9.1	7.5	8.0	8.2	12.2	10.8	7.0	8.7	12.3	10.2	12.2	10.8	12.8
Montana	1.9	2.0	4.4	2.8	1.1	.9	1.7	.9	.9	1.1	.8	2.4	.8
Wyoming	2.0	2.5	.4	1.6	1.9	3.4	.7	1.1	.5	1.5	.3	.5	.4
Colorado	3.1	2.0	2.5	2.5	2.4	1.5	2.3	3.0	1.6	2.2	1.7	.9	1.8
New Mexico	1.5	1.7	1.5	1.6	1.8	.8	2.0	1.0	3.0	1.7	.9	.2	.5
Arizona	1.0	1.5	2.0	1.5	9.4	5.3	2.2	2.2	2.1	4.2	.8	.2	.1
Utah	4.2	.6	4.0	2.9	1.4	1.0	2.0	.5	1.1	1.2	.9	1.2	1.3
Nevada	3.0	4.0	2.0	3.0	2.1	1.8	1.6	1.0	1.9	1.7	4.7	.6	.2
Idaho	1.1	1.3	1.5	1.3	1.1	2.8	2.5	2.4	2.3	2.2	1.5	3.8	.3
Washington	1.5	1.8	1.3	1.5	1.6	2.0	1.8	2.4	2.3	2.0	3.3	1.1	1.1
Oregon	1.6	1.0	1.2	1.3	1.5	1.3	2.7	2.7	3.0	2.2	2.2	1.5	1.8
California	2.5	5.0	3.2	3.6	3.3	4.5	5.7	6.1	5.3	5.0	2.8	5.6	3.3
United States	5.2	4.9	5.1	5.1	5.1	5.8	5.8	5.2	7.5	5.9	6.4	8.2	9.3

[a] Three years. [b] Two years.

March 31, and the average for each period indicated—Continued.

SWINE.

1897.	1896.	Five-year average.	1895.	1894.	1893.	1892.	1891.	Five-year average.	1890.	1889.	1888.	1887.	1886.	Five-year average.
2.3	2.0	1.7	3.4	0.8	1.6	1.4	1.7	1.8	2.2	1.3	1.4	4.0	5.0	2.8
2.3	2.2	2.2	2.4	3.4	1.6	1.6	2.0	2.2	2.0	1.8	2.0	4.0	3.0	2.6
2.4	1.8	2.0	5.1	1.5	3.3	1.8	1.7	2.7	2.2	1.5	1.8	3.0	3.0	2.3
1.8	1.6	1.8	2.2	2.0	2.3	1.4	2.0	2.0	2.0	1.3	2.3	4.0	4.0	2.7
2.3	2.1	2.4	1.8	2.7	1.6	1.7	1.6	1.9	1.8	1.5	1.3	3.0	3.0	2.1
2.5	1.0	1.7	4.3	4.7	3.7	2.3	2.5	3.5	1.8	1.4	2.0	5.0	3.0	2.6
3.2	3.2	2.7	2.6	2.8	3.1	1.9	2.0	2.5	2.5	2.5	2.2	4.5	4.0	3.1
3.2	6.5	4.1	9.2	1.4	1.4	1.8	2.4	3.2	2.0	2.0	1.6	5.0	3.0	2.7
3.1	3.6	3.1	3.0	2.1	2.8	2.0	2.7	2.5	3.0	2.3	3.0	9.0	4.0	4.3
5.3	4.0	5.1	....	....	3.1	4.0	5.0	a 4.0	7.0	10.0	3.7	6.5	8.0	7.0
5.8	3.5	4.9	4.5	2.3	2.3	3.5	4.5	3.4	6.4	4.1	7.3	20.0	12.0	10.0
7.5	6.5	6.0	4.4	3.0	6.5	5.3	5.5	4.9	7.5	5.0	7.4	27.0	12.0	11.8
7.0	5.0	5.9	2.3	2.2	2.8	5.0	4.5	3.4	8.6	4.8	6.7	10.0	6.0	7.2
9.8	11.0	8.5	8.1	6.1	9.5	7.0	7.2	7.6	10.0	6.3	8.0	20.0	13.0	11.5
9.1	11.0	8.6	10.0	8.5	7.2	6.2	5.0	7.4	8.5	7.5	7.4	13.0	14.0	10.1
12.6	11.5	10.7	10.2	7.6	10.5	9.7	8.5	9.3	9.0	13.0	7.5	15.0	13.0	11.5
10.8	13.0	11.8	13.6	8.1	20.0	7.5	11.0	12.0	10.7	12.5	9.0	13.0	25.0	13.8
10.8	8.2	7.5	5.0	3.3	3.4	4.0	6.0	4.3	5.4	3.8	5.7	8.0	5.0	5.6
23.8	14.8	12.9	7.5	3.0	5.0	6.0	9.4	6.2	9.3	6.5	9.0	11.0	7.0	8.6
14.5	24.2	13.3	14.5	3.9	5.3	7.5	8.5	7.9	7.0	6.0	8.6	18.0	15.0	10.9
3.5	3.8	3.5	2.3	1.7	2.0	5.2	3.5	2.9	4.0	2.3	6.1	5.0	5.0	4.5
3.3	4.1	4.1	4.9	3.2	4.0	4.1	4.2	4.1	3.2	4.6	5.7	5.0	4.0	4.5
9.2	5.3	9.8	3.6	2.0	2.6	4.0	2.4	2.9	3.0	3.4	2.6	4.0	3.0	3.2
32.9	20.7	19.2	10.6	4.2	8.4	5.3	8.2	7.3	7.5	5.0	8.2	10.0	13.0	8.7
16.7	20.0	12.7	11.6	5.8	5.4	5.0	12.0	8.0	8.0	6.7	9.5	18.0	16.0	11.6
4.8	2.0	2.6	2.2	1.2	3.8	3.2	4.5	3.0	7.5	3.4	4.7	6.0	8.0	5.9
14.4	9.0	11.1	7.1	4.0	3.5	2.9	4.5	4.4	7.5	3.4	4.7	6.0	8.0	5.9
15.9	13.6	11.9	12.6	5.6	4.6	4.0	14.5	8.3	8.5	5.5	8.5	10.0	17.0	9.9
10.8	13.0	8.7	7.8	4.5	4.0	3.7	10.0	6.0	5.8	5.8	7.7	13.0	18.0	10.1
15.6	10.5	10.5	14.2	6.9	5.5	4.2	9.8	8.1	9.5	6.3	8.0	12.0	9.0	10.0
13.8	12.0	10.8	16.2	7.1	5.0	7.2	10.0	9.1	9.3	9.7	11.7	19.0	13.0	13.1
14.0	13.0	10.0	11.6	6.9	12.0	8.0	8.2	9.3	10.3	11.0	8.0	17.0	20.0	13.3
15.2	12.0	9.8	8.8	5.8	9.0	8.6	8.2	8.1	11.5	8.0	9.0	20.0	18.0	13.3
27.5	11.5	14.8	9.4	6.2	10.6	5.3	9.4	8.2	9.3	9.0	9.5	18.0	16.0	12.4
11.6	8.0	6.6	6.0	4.7	5.9	3.7	7.8	5.6	7.5	5.5	7.3	13.0	20.0	10.7
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
5.4	2.5	3.6	....	....	....	....	....	....	....	....	....	....	....	....
21.0	18.0	15.0	11.2	8.3	12.3	8.6	11.0	10.3	10.6	10.5	12.5	20.0	22.0	15.1
4.3	.8	1.8	3.5	1.4	1.5	2.0	3.0	2.3	6.0	2.5	3.0	8.0	5.0	4.9
.8	1.7	.7	0	1.0	1.0	1.5	4.0	1.5	5.0	2.5	3.5	5.0	3.0	3.8
2.7	6.0	2.6	3.0	1.5	1.2	1.6	2.2	1.9	5.0	2.0	4.0	5.0	3.0	3.8
5.8	2.6	2.0	1.7	1.0	1.2	3.7	4.3	2.4	5.0	6.7	8.0	6.0	6.0	6.3
9.0	1.3	2.3	3.2	....	1.5	3.0	3.0	c 2.7	6.0	2.5	4.0	5.0	3.0	4.1
3.0	2.0	1.7	3.2	1.1	2.3	1.5	4.0	2.4	5.4	5.0	5.1	4.0	4.0	4.7
1.5	2.3	1.9	0	8.0	3.5	3.2	2.5	3.4	3.5	2.0	3.0	8.0	5.0	4.3
4.1	2.0	2.3	.7	....	3.0	3.0	3.2	c 2.5	6.0	3.0	3.7	5.0	5.0	4.5
3.6	3.0	2.4	2.1	2.4	1.0	2.5	2.5	2.1	5.8	2.6	2.7	4.0	5.0	4.0
3.5	2.2	2.2	1.2	1.0	3.7	2.4	2.3	2.1	6.7	2.3	3.0	5.0	3.0	4.0
5.2	8.0	5.0	4.9	1.8	2.9	3.1	4.8	3.5	5.9	2.5	4.0	10.0	5.0	5.5
14.4	12.7	10.2	9.2	4.9	6.3	5.4	8.4	6.8	7.6	6.2	7.8	13.4	13.0	9.6

a Four years.

DISEASES OF LIVE STOCK.

By A. D. Melvin,
Chief of Bureau of Animal Industry, U. S. Department of Agriculture.

The Bureau of Statistics of this department has submitted to the commission a statement showing the estimated losses of farm animals from disease and exposure for a number of years. The commission should consider in its report the losses from exposure as well as those from disease, as such losses are unquestionably large in the open range country during severe winters. It is believed that the numbers lost could be greatly reduced by leasing the range and allowing stock owners to fence it and to build sheds for the protection of the animals.

There is no doubt that by far the greater part of the losses of hogs from disease is due to hog cholera. For several years this bureau has been making investigations to determine the cause and develop a remedy, and recently a method of treatment has been worked out which is shown to be very effective in preventing the disease. The department is now endeavoring to induce the authorities of the various States to undertake the production of serum or vaccine according to the bureau's method and to supply this remedy to hog raisers in their respective States. If this plan can be carried out, especially in the large hog-raising States where cholera prevails, losses on account of this disease can unquestionably be greatly reduced.

The southern cattle tick (*Margaropus annulatus*) is the cause of heavy losses to the live-stock industry in the section where this parasite prevails. The infected area includes all or parts of the States of Virginia, North Carolina, South Carolina, Tennessee, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas, and California. This tick not only spreads the contagion of southern or Texas fever of cattle, but does considerable injury to the animals simply as a bloodsucking parasite. It is estimated that this tick is responsible for an annual loss of about $40,000,000 to the people of the infected country and that it also lowers the assets of the South by an additional $23,250,000.

The remedy for this condition is to exterminate the ticks, and this work has been in progress since the summer of 1906 by cooperation between the federal and state authorities. Within that time an area of over 63,000 square miles has been freed from the ticks and the practicability of their ultimate eradication has been demonstrated, although the undertaking will undoubtedly require several years and the expenditure of considerable money. It is believed, however, that the benefits will amply justify the expenditure.

Other sources of losses are the diseases known as scabies of sheep and cattle. Before this bureau undertook to control and eradicate these diseases, their presence in this country threatened serious injury to our export trade in live stock. While these diseases are not often directly fatal, they reduce the strength and vitality of the animals to such an extent that many die from exposure during severe weather.

There are also losses from reduction in flesh, and, in the case of sheep, decrease in wool production. For several years this bureau, in cooperation with State authorities, has been endeavoring to eradicate these diseases and good progress has been made. They have been entirely wiped out in several States and by continuing the work there is no question that they can be completely obliterated from the United States in the course of a few years.

Tuberculosis is perhaps the disease which causes the heaviest losses to the live-stock industry. During the fiscal year 1908 there were found affected with tuberculosis 0.96 per cent of the adult cattle and 2.05 per cent of the hogs examined in the federal meat-inspection service. Taking these figures in connection with reports of the tuberculin test on dairy cattle, it is estimated that more than 1 per cent of beef cattle, 2 per cent of hogs, and about 10 per cent of dairy cattle in the United States are affected with tuberculosis.

A careful study was recently made, followed by an estimate of the economic loss from this disease, and it was found that the loss probably exceeds $14,000,000 a year. Some of the items making up this amount are the loss on animals found tuberculous in the meat inspection, the depreciation in the value of the stock of farm animals remaining alive, the decrease in the milk yield of tuberculous cows, the impairment of breeding qualities, the increased cost of wholesome meat and dairy products, and injury to the trade in live animals and meats.

The remedy seems to be to eradicate tuberculosis from the farm animals of the country, and this is believed to be entirely practicable, although it will necessarily be a large and costly undertaking. The expense, however, will unquestionably be justified by the results. It has been clearly shown that hogs readily contract tuberculosis from cattle and that diseased cattle are the primary source of the infection in hogs. The main problem, therefore, is to eradicate the disease in cattle.

Live-stock owners should be aroused to the danger of having tuberculosis among their animals and should be educated as to the nature of the disease and the best methods of combating it. Valuable work in this direction may be done by the general and agricultural press and by official publications, also by lectures at public gatherings, farmers' institutes, etc.

The real work of eradicating tuberculosis, however, must be done by the federal and state governments in cooperation. There should be a systematic effort to determine to what extent and in what localities the disease exists, and the tuberculin test should be applied to cattle in such sections. The safest way of disposing of infected animals is to slaughter them. In order to reduce the financial loss to a minimum and at the same time guard against the sale of unwholesome meat, animals should be slaughtered at abattoirs under federal or other competent veterinary inspection. In this way a large proportion may be safely passed for food and made to yield its full meat value, while only those animals whose meat may be dangerous to health will be condemned.

An effective means of locating and eradicating tuberculosis of live stock would be to establish by state legislation a system of tagging cows sent to market for slaughter from suspected districts, so that if any were found tuberculous in the meat inspection, they could be traced back to the place of origin, thus locating centers of infection. The Bureau of Animal Industry is already cooperating with the authorities of some States by reporting on tuberculous animals, and the results so far have been very encouraging. To give the plan general application authorities should be empowered by law to require that shippers shall tag their cows in such a way that they may be identified and their origin determined.

Inspectors should be stationed at important points for the purpose of testing cattle for breeding and dairy purposes, and each State that is endeavoring to eradicate the disease should require that no cattle for breeding or dairy purposes shall be admitted from outside the State unless they have passed the tuberculin test. A good method of preventing the spread of tuberculosis among breeding stock would be the establishment by the State of one or more free herds of breeding cattle for the use of stock raisers in the State, or the State could certify to the health of free herds.

As the eradication of tuberculosis is largely a public health measure, it is not only reasonable that the State should compensate at least in part the persons whose cattle are slaughtered, but it is absolutely essential if the cooperation of cattle owners is to be secured.

The agricultural appropriation act for the current fiscal year authorizes the Secretary of Agriculture to investigate the prevalence and extent of tuberculosis among dairy cattle in the United States, and steps are being taken by this bureau to collect such information. Before any effective or extensive work of eradication can be undertaken, however, larger appropriations will be necessary.

A recent compilation and study of state laws on the subject show that very few States have adequate laws for the protection of live stock from contagious diseases and for the control and eradication of such diseases. Furthermore, very few States have made anything like adequate appropriations for the necessary expenses of effective work. An essential step toward any comprehensive work dealing with such diseases will be the enactment of proper legislation by the various States where this is lacking, and the appropriation of sufficient funds to carry on the work.

SHRINKAGE IN ANIMAL PRODUCTS DUE TO INJURIOUS INSECTS.

By C. L. Marlatt,
Bureau of Entomology, U. S. Department of Agriculture.

All domestic animals suffer seriously from parasitic and other insects, and above the reduction in the annual output of products is the heavy loss occasioned by certain insect pests to such stored and manufactured animal products as hides and furs, and stored animal food products. There is also the very serious check on production caused by the prevalence of certain insect-borne diseases of domestic animals. This last source of loss, however, is taken up elsewhere.

The value to the farmer of all animal products for the year 1907 is given in the report of the Secretary of the United States Department of Agriculture for that year as $2,678,000,000. This represents the products actually sold or consumed, and not the stock animals. Beef and dairy and all other domestic animals, including poultry, are subject to the attacks of biting and parasitic insects which operate as a very considerable check on fattening or on the yield of salable products. In the case of cattle the principal culprits are the ox warble and various biting flies and ticks. The damage chargeable to the ox warble was very carefully investigated several years ago by a western farm paper, and from the averages reported from the chief cattle States of the Mississippi Valley it was shown that 50 per cent of the cattle received in the Union Stock Yards at Chicago during the grubby season (from January to June) were infested and more or less injured by the presence of the larvæ of this insect. The depreciation in the value of hides and the lessened quantity and poorer quality of the beef indicated a total loss during the season of over $3,000,000. This loss applies only to the cattle coming to the Chicago market during the period mentioned, and is merely an indication of the much greater loss to range and farm stock throughout the country from this one pest. The loss for Great Britain from the warble has been estimated to vary from $10,000,000 to $35,000,000 per annum, and the total for the United States certainly can not fall below that for Great Britain.

The shrinkage or check to fattening or lessening of milk production, due to the annoyance from biting flies and other insect pests of cattle, represents a very considerable total every year; probably, in view of the greater prevalence of these pests, much more than is chargeable to the ox warble.

The loss to cattle production and values due to ticks (particularly the southern cattle tick responsible for Texas or splenetic fever) is enormous from the standpoint of the disease mentioned. This phase of the question, however, falls under a different section. Nevertheless, merely as parasites, ticks are a very serious pest in the South, seriously affecting the health and productive capacity of cattle.

Horses, sheep, and other farm animals, including poultry, are subject to the attacks of similar parasites and other insect enemies, and if all these be considered, including, for example, the buffalo gnats, often very destructive in the South, the many gadflies, botflies, the screw-worm fly, and such parasites as ticks and lice, a heavy percentage of loss must be reckoned. A 10 per cent annual loss has been assigned, certainly a conservative estimate, which represents a shrinkage for 1907 of $267,000,000 in value of animal products due to insect pests.

CONTROL OF INSECT ENEMIES OF LIVE STOCK.

A very large percentage of the loss to animal products from insect attack can be saved by the more general adoption of known remedies, but many of the problems are still under investigation. The tick problem is being actively investigated, and a rather simple method of rotation of pasturages seems to offer a practical means of control, and, under favorable conditions, of absolute extermination. A knowledge of the life history of biting flies and various internal parasites makes it possible to control these pests also in a considerable measure by limiting their breeding places and protecting cattle by the use of repellant washes or lotions. Such parasites as ticks and lice can also be controlled by intelligent quarantining.

THE PUBLIC RANGE.

By A. F. POTTER,
United States Forest Service.

GENERAL DESCRIPTION.

There is no other natural resource of the country in which the people at large are more directly interested than in the use of the forage crop which grows upon the public lands. That there is a vast amount of land not at present susceptible of cultivation and so located that it can not be reclaimed by irrigation, which, for at least a long time to come, will be valuable only for grazing purposes, is a well-established fact.

The area of this land is probably not less than 300,000,000 acres, and includes parts of all the Western States. There is also a large area of partially wooded land, some of which has been included within the national forests, the principal agricultural value of which at present is for grazing live stock. In addition there is also land which can be reclaimed by irrigation, and a limited area upon which crops can be grown under favorable climatic conditions through dry farming, but which in the meantime is used only for grazing.

Most of this land has been occupied for many years by the stockmen of the West with their cattle, horses, sheep, and goats, and a large portion of the supply of beef, mutton, and wool furnished the markets of the United States has come from the herds and flocks grazed upon these public lands.

The use of the public lands, excepting such areas as have been withdrawn for national parks, national forests, military reservations, or other like public purposes, has always been free and unrestricted. This was a great advantage to the settlers on the frontier, and resulted in the establishment of many homes in localities where the lands were valuable only for grazing, but, on the other hand, it has resulted in serious abuse of the lands by persons who engaged in the live-stock business upon a speculative basis.

A very large proportion of the annual crop of grasses and forage plants can not be cut and kept for future use, but must be harvested by driving the live stock to the grazing grounds and allowing them to feed upon it. In this way the forage crop is converted into a marketable product, which adds very greatly to the general prosperity of the people and to the wealth of the nation.

The stockmen are thus enabled to make profitable use of the products of a very large area of foothills, plains, and desert lands which otherwise would go to waste. It is plain, then, that grazing is not only a source of prosperity under ordinary circumstances, as a close companion to agriculture, but is also one of the most important means of producing revenue from lands that are outside of the limits of profitable cultivation.

In the western range country stockmen have been among the earliest pioneers, and grazing has been the means of opening the way to other pursuits, because the herdsman with his cattle, horses, and sheep took possession of the frontier and opened up the way for tillers of the soil.

The evolution of the western range from grazing to cultivated land is brought about largely in the following manner: A portion of the range is fenced in order that the stock may be kept under control. The stockman prospects around for water, cleans out and improves the flow of springs, and finds places where water can be had by digging wells. Having succeeded in getting his pasture sufficiently watered for grazing purposes, he then gives his attention to seeing what can be done in the way of raising winter feed. Portions of the best land are set aside for cutting wild hay and experiments are made in raising cultivated forage crops. Where there is sufficient water for irrigation, the land is usually seeded with alfalfa, and immediately furnishes an increased amount of forage. The result is that it is soon found that the grazing capacity of the area has increased and the quality of the stock improved. This attracts the attention of others, and soon new divisions of the range are made. Settlers are attracted by the success of the stockmen in raising winter feed for their stock and try more varied farming. Thus the country changes to a more thickly settled and prosperous condition, and the successful establishment of homes is made possible upon the range lands.

On July 1, 1906, the total area of vacant public land was 418,358,752 acres. During the past ten years the average amount of public land disposed of annually has been about 18,000,000 acres. About two-thirds of the entries have been made under the homestead act. At this rate it will only be a few years until all of the land suitable for cultivation will have passed into private ownership. This does not mean that a less number of stock will be raised, but that a greater proportion of the animals will be fed upon the products of the cultivated lands, and that the need for an economic use of the remaining vacant lands will be increased proportionately, because in many instances the stock must be pastured on outside range during the growing period of the cultivated crop.

In reply to the questions asked in a circular sent out by the National Conservation Commission, 35 per cent of the stockmen heard from stated that they fed all of their stock upon the products of cultivated lands during the winter season, 35 per cent stated that they fed at least a portion of their stock during the winter, while only 30 per cent of the whole number reported that all their stock were pastured upon the open range during the entire year. This shows very plainly the close connection between grazing and agriculture, and indicates that beyond a doubt the practice of winter feeding is being adopted in many localities. The result will be to decrease the winter losses and place the live-stock industry on a much safer basis.

CAUSES OF DECREASE IN GRAZING VALUE.

At first, when the public lands were used only by the pioneers with their small bands of stock, there was an abundance of range for all and no one gave any thought to the future, but it was not long before men from the more thickly settled sections of country, where the ranges were becoming crowded, commenced to move westward in search of better opportunities, and gradually the range became more and more crowded.

The first effect of this was that the stock did not fatten as in former years, and consequently did not bring as good prices when marketed. Then, on account of the stock being in poorer flesh, the winter losses commenced to become greater and the percentage of natural increase smaller.

In localities where overstocking continued the grasses and forage plants were gradually trampled out until in many sections the grazing value of the lands was almost entirely destroyed. This was naturally followed by very serious losses of stock, particularly in seasons of drought.

The damage has not been done by any one kind of stock, but by all during different periods or in different localities. In the early eighties there was a great boom in the cattle business, and immense herds were driven to the ranges of the Southwest. It was only deemed necessary to secure a few watering places before turning loose unlimited numbers of stock upon the open range. There was no law to prevent overcrowding or to authorize any control whatever over the use of the lands. Under this condition of affairs it was not long until serious contentions arose, and out of it grew the notorious Lincoln County war in New Mexico and the Tonto Basin war in Arizona, both of which resulted in serious loss of life and property. While all of this was going on the carrying capacity of the range was gradually being diminished by grazing excessive numbers of stock, so that when in the early nineties there was a serious drought, the forage crop was entirely inadequate to support the number of animals, and a very large percentage died from starvation. At this same time the market prices for cattle and horses declined very greatly and many of the stockmen were compelled to close out their business through inability to make any profit or to meet their indebtedness. During this period the prices of sheep were also very low, but in the late nineties prices of wool and mutton began to improve, and many of those who had formerly raised cattle and horses engaged in the sheep business. The era of prosperity in sheep raising has continued up to the present time, and there is still a very great demand for the use of range by this kind of stock. The fact that sheep are herded has given their owners a great advantage on the open range, as herds are easily moved to localities where the feed is best or where there is available range.

There has been much complaint regarding the crowding in of sheep on ranges claimed by the cattlemen, and in many cases there has been serious conflict. In some localities the cattle owners through organized action have succeeded in keeping sheep off the ranges used by their cattle, but it is generally admitted that the increase in the number of sheep has compelled many of the smaller owners to discontinue raising cattle and to seek some other means of making a livelihood.

In such localities, and in many localities where no opposition was offered by the cattlemen, the number of sheep has increased until in the competition for range there has been very little regard for the interests of the public, and it has become a constant race from place to place in search of the most favorable feeding grounds.

The lack of control in the use of these lands has resulted in overgrazing and the ruin of vast areas of otherwise valuable range.

In response to a circular sent out by the Public Lands Commission in 1904, requesting information regarding the condition of the public-grazing lands, 80 per cent of the stockmen heard from reported the carrying capacity of the ranges they were using to have diminished, and 80 per cent of those making such report attributed the decrease to overstocking. Practically the same results have been obtained from a circular sent out this year by the National Conservation Commission, and, therefore, it is evidently a well-established fact that damage to the public-grazing lands is due almost entircly to the lack of any system or authority for its control.

METHODS FOR IMPROVEMENT OF GRAZING LANDS.

The most general method adopted by stockmen to control the use of public grazing lands has been through securing title to the watering places. If all of the water on a range could be secured, this has usually been recognized as giving the owner a right to the use of adjoining lands for grazing purposes, because in case of controversy he could fence up the water and thus prevent stock other than his own from using the outside lands.

However, the cases in which very large areas have been controlled in this way are exceptional, and as a rule it has only been successful as a means of securing the exclusive use of comparatively limited areas.

The most practicable method of controlling the grazing of stock is by fencing the lands into pastures. It has been found that wherever the lands were protected by fencing and overstocking stopped, the condition of the range at once improved and the amount of forage increased; better care is taken of the stock; losses from straying and death are lessened; a better grade of stock is raised, and in every way a better use of the land is obtained. Recent experiments made by the Forest Service in the use of fenced lands for the summer grazing of sheep have proven conclusively that they will carry 50 per cent more stock and at the same time produce better animals than are raised on the open range where the stock must be herded. Lambs raised in an experimental pasture in the State of Oregon weighed 10 pounds more than the same age and grade of lambs raised on the outside range.

In all of the Western States it is universally true that steers which are pastured on range controlled by fences outweigh steers from the open range and bring better prices on the market.

Experience in the management of grazing upon the national forests shows that upon ranges which were overgrazed prior to the enforcement of proper regulations a very large percentage of the forage is wasted through stock entering upon the range too early in the season, while the feed is immature. In the absence of any restriction there is always a race for feed in the early part of the season, each stockman trying to get upon the summer range first, in order to establish camps and hold the range. The serious damage caused by trampling is immediately stopped when the stock is kept off until the feed has a chance to get fairly started. In fixing the periods during which stock are allowed to graze within the forests, an endeavor is made to meet local conditions as nearly as possible and to allow the use of each district during the period when it is most needed and can be used to the best advantage.

By dividing the ranges into separate grazing districts and allowing the use of the lands by the kind of stock for which it is best adapted and during a proper grazing period, an increase of at least one-third has been made in the amount of forage utilized. Last year is was possible to increase the number of stock grazed upon 30 of the national forests on account of the improvement in the condition of the range which had been brought about by proper regulation.

In the answers which were received to the circular sent out by the Public Lands Commission in 1904, 15 per cent of those reporting improvement in the condition of their range attributed it to national forest regulation. Of the stockmen who, in response to the circular sent out by the National Conservation Commission this year, reported an increased amount of forage upon their ranges, 25 per cent credited the improvement to national forest regulation. This is a very satisfactory showing of the practical results which have been obtained and indicates that without doubt rapid advancement is being made in restoring the former grazing value of the lands.

Throughout the western range country the market for hay and other products of irrigated land depends very largely upon feeding live stock. In many places remote from transportation farming is only made profitable through raising live stock to consume the products of the farm. Cattle and sheep which are pastured in the mountains during the summer are driven to the fields in the fall after the crops have been harvested, and there fed during the winter.

As new areas are reclaimed and brought under cultivation by the Government and by private enterprise, the proper use of grazing lands in their vicinity becomes a matter of very great importance, because if the lands forming the watersheds of the streams are abused by overgrazing or improper grazing, then the water supply is diminished and, if the lands are not used for grazing, then the most profitable means of marketing the products of the land is removed.

The solution of this problem lies in the control of grazing upon the public lands and the enforcement of such regulations as are necessary to insure their permanent use for grazing purposes.

THE PUBLIC RANGE.

By A. D. Melvin,
Chief of Bureau of Animal Industry, U. S. Department of Agriculture.

From personal observation and from reports received from inspectors, there is no doubt that on the whole the carrying capacity of the public range has decreased.

This decrease is due to (1) the taking up of the public range by homesteaders, and (2) overstocking and misuse. The ranges have been overcrowded, especially at certain seasons and in the vicinity of watering places, and close grazing and trampling have in some places almost exterminated the native grass.

Measures should be taken to prevent overstocking and to protect the range so that the supply of grass may be renewed. There should be some system of government regulation of grazing on the public range. This could probably be best accomplished by leasing the range to stock owners and allowing them to fence the land. By this means the range would be brought under definite proprietorship, the lessees exercising control over the land and regulating the number of animals, which would encourage them to make improvements aiding in the conservation of both live stock and range. Such a plan would also assist in the control of contagious diseases and in the protection of live stock during the winter, two matters which are practically impossible of accomplishment on the open range under present conditions.

Reseeding the range where the natural grass has been destroyed would also be advantageous.

SWAMP AND OVERFLOW LANDS.

By Robert Follansbee,
United States Geological Survey.

INTRODUCTION.

The following report has been prepared in response to an inquiry from the National Conservation Commission regarding the area and ownership of the swamp lands of the United States, together with the cost and present status of reclaiming them.

In giving general estimates of swamp areas in the various States, the report of Prof. N. S. Shaler, published in the Tenth Annual Report of the United States Geological Survey, was used as a basis. The figures were modified, however, as further investigation showed them to be in error, or where subsequent reclamation work has changed their value.

The data regarding the present ownership have been derived mainly from the secretaries of state for the various States.

As the cost of reclaiming the swamp areas has varied widely, no attempt has been made to generalize, but instead typical examples in different sections of the country have been described as far as possible. These can be used as a basis for estimating the cost of future work. The data as presented were obtained for the most part from engineers and landowners directly interested, and should therefore be reliable within the limits noted elsewhere.

The data regarding the present status of the work have been compiled from various sources, mainly through the technical press and through correspondence.

ESTIMATE OF SWAMP AND OVERFLOW AREAS.

As noted in the introduction, the basis for the estimate of swamp areas in each State was Professor Shaler's report on swamps. His estimates have been modified either where a sufficiently large percentage of a State has been topographically mapped to show that such a change is necessary, or where information acquired by a personal visit to the State has shown them to be in error.

Wherever possible an attempt has been made to differentiate between permanent swamp and land periodically overflowed to such an extent as to render cultivation hazardous. But as Professor Shaler made no such distinction, it is not possible at present to separate the two types in the majority of cases. Also where the estimates were based on the topographic sheets they do not include the overflow lands, but it is believed there is not a great amount of land seriously overflowed in those States, with the possible exception of New Jersey and Oklahoma. Accompanying each estimate is a statement regarding its source. in order that some idea may be formed regarding its accuracy.

Swamp and overflow areas.

State.	Area (acres).	Autbority.
Alabama	1,120,000	Sbaler.
Arkansas	5,760,000	Do.
California	1,850,000	The area in Sacramento Valley was measured from a map of that section issued by the State in 1906, while the remainder of tbe area was obtained from the Land Office map.
Connecticut	37,700	State entirely mapped topographically, and estimate obtained by direct measurement.
Delaware	200,000	38 per cent of estimated swamp area mapped. Remainder uncertain.
Florida	18,560,000	Shaler.
Georgia	2,400,000	Do.
Illinois	2,688,000	This represents overflow areas along tbe streams as given by the State Geological Survey. It is estimated that 90 per cent of this area is either wholly or inadequately protected against floods, but if protection were afforded $150,000,000 would be added to the farm values of tbe State. Tbe uplands are practically drained.
Indiana	1,000,000	This includes 600,000 acres of overflow land along the Wabash, West Fork of Wbite, and Ohio rivers where levee protection is needed. Estimated from direct measurement of map compiled in field by writer. The remainder of the swamp area is found principally along Kankakee River, as most of the uplands are drained.
Iowa	800,000	Estimate based on tbe writer's knowledge of general conditions in the State. Areas found chiefly in north-central part and on Missouri slope. Drainage is progressing so rapidly that estimates must be revised frequently.
Kansas	160,000	Shaler.
Kentucky	224,000	Do.
Louisiana	9,600,000	Do.
Maine	240,000	The average swamp area per square mile for New York, New Hampshire, and Vermont was taken as the area per square mile for Maine.
Maryland	356,000	Swamp area practically mapped. Estimated from direct measurement.
Massachusetts	138,700	State entirely mapped topograpbically. Estimated from direct measurement.
Michigan	4,400,000	Sbaler's estimate reduced somewhat to allow for land already drained.
Minnesota	4,500,000	Estimate based on Shaler. State has received 4,500,000 acres under swamp act. State drainage engineer estimates tbat there were 10,000,000 acres too wet for agriculture, of which 3,000,000 acres have been drained.
Mississippi	6,173,000	State Geological Survey.
Missouri	1,920,000	Sbaler. Area chiefly in southeastern part of State.
Nebraska	256,000	Shaler.
New Hampsbire	43,000	30 per cent of State mapped topographically. Assuming same ratio of fresh marsh to dry land mapped to hold true for entire State gives 37,400, or 43,000 acres of both fresh and salt marsh.
New Jersey	601,900	State entirely mapped. Estimated from direct measurement.
New York	576,000	81 per cent of swamp area mapped topographically.
Nortb Carolina	2,400,000	Sbaler.
North Dakota	226,000	Do.
Ohio	200,000	Based on writer's knowledge of general conditions.
Oklahoma	35,000	Includes Indian Territory. Swamp area practically mapped. Estimated from direct measurement.
Oregon	500,000	48 per cent of swamp area mapped. Remainder of area obtained from Land Office map.
Pennsylvania	96,000	52 per cent of swamp area mapped. Remainder of area somewbat uncertain.
Rhode Island	17,900	State entirely mapped. Estimated from direct measurement.
South Carolina	1,760,000	Shaler.
South Dakota	226,000	Do.
Tennessee	800,000	Do.
Texas	1,620,000	Do.
Vermont	70,000	Of area of State, 39 per cent mapped topographically. Estimate based on assumption tbat ratio of swamp to total area mapped applied to entire State.
Virginia	384,000	60 per cent of swamp area mapped. Remainder estimated from knowledge of general conditions.
Wasbington	75,000	52 per cent of swamp area mapped. Remainder of area uncertain.
West Virginia	2,500	State entirely mapped. Estimated from direct measurement.
Wisconsin	2,500,000	Shaler's estimate reduced somewhat to allow for land already drained.
Wyoming	25,000	Swamp area practically all mapped. Estimated from direct measurement. This is exclusive of Yellowstone National Park.
Total	74,541,700	

OWNERSHIP.

Under the swamp act of 1850 practically all the public swamp lands have been donated to the States in which they are located, with the proviso that the funds derived from their sale shall be used to reclaim them. As a result, not more than 1,300,000 acres, approximately, remained as public lands June 30, 1907 (see Land Office circular on unappropriated lands). Such lands were donated only to the States existing in 1850, not to those thereafter admitted. These lands were located as follows:

	Acres.
Alabama	5, 000
Arkansas	17, 000
Florida	78, 900
Louisiana	4, 600
Minnesota (approximately)	1, 200, 000
Wisconsin	2, 200
Total	1, 307, 700

This is approximately 1.7 per cent of the entire swamp area of the country.

The Commissioner of the Land Office for 1907 gave the following summary of swamp-land claims that had been approved:

Swamp-land claims approved and certified under various grants.

State.	Claims approved—total since dates of grant.	State.	Claims approved—total since dates of grant.
	Acres.		*Acres.*
Alabama	419, 325. 76	Minnesota	4, 533, 588. 77
Arkansas	7, 695, 637. 26	Mississippi	3, 341, 057. 98
California	2, 078, 444. 93	Missouri	4, 498, 573. 28
Florida	20, 458, 866. 46	Ohio	26, 271. 95
Illinois	1, 497, 028. 35	Oregon	355, 749. 62
Indiana	1, 266, 075. 75	Wisconsin	3, 353, 067. 86
Iowa	942, 180. 67		
Louisiana	9, 385, 026. 27	Total	65, 582, 503. 59
Michigan	5, 731, 608. 68		

The following table shows the amount of swamp lands still owned by the States, and also what disposal has been made of the remainder:

State ownership of swamp lands and method of disposing of remainder.

State.	Owned by State.	Disposal of remainder.
Alabama	0	State granted lands to trustees of Alabama insane hospitals.
Arkansas	200	
California	0	Practically all held in private ownership.
Connecticut [a]	0	Lands held in private ownership.
Florida	2,640,000	9,230,000 acres granted to private parties, canals, etc.; 8,280,000 acres granted to railroads.
Georgia	0	Practically all held in private ownership.
Illinois	0	State conveyed lands to counties, which sold them to individuals.
Indiana	0	Practically all held in private ownership.
Iowa	0	State conveyed lands to counties, which sold them to individuals.
Louisiana	0	State conveyed lands to various levee boards, which sold them to individuals.
Michigan	9,500	Remainder sold to individuals and proceeds of a part spent in reclamation work. The rest were disposed of under state homestead laws.
Minnesota	2,500,000	Remainder sold to individuals.
Mississippi	10,000	Remainder sold or donated to commissions for the improvement of certain rivers.
Missouri	0	Prior to 1869 some lands patented to individuals, but after that date the lands were conveyed to the counties.
New Jersey [a]	100	Remainder held in private ownership.
New York [a]	100	Do.
North Carolina [a]	230,000	These lands are owned by the state department of education. The remainder of the swamp lands are held in private ownership.
Ohio	0	Practically all held in private ownership.
Oregon	1,000	
South Carolina [a]	0	Lands granted to individuals.
Texas [a]	....	(No data.)
Virginia [a]	0	Practically all held in private ownership.
Wisconsin	50,000	2,000,000 acres sold for benefit of normal school fund. Remainder sold for benefit of general fund. The lands still owned by the State have recently been appropriated for a forest reserve.

[a] States did not receive lands under swamp act. In the States omitted from the above list the swamp areas are small and are chiefly owned by individuals.

COST AND RESULT OF RECLAIMING SWAMP LANDS.

The cost of reclaiming the swamp lands in the United States has varied so widely that no attempt will be made to reach general conclusions on the subject. Instead, typical examples in different parts of the country will be given in order that a basis may be formed for estimating the cost of future work.

With regard to the manner of reclamation, wet lands may be divided into two classes—(1) those requiring protection by levees from periodical overflows, with additional interior drainage; and (2) those that are wet the most of the year owing to defective natural drainage. This latter type is found not only along the rivers, but also on the uplands and frequently on divides. It comprises the greater part of the wet land and is, fortunately, capable of being reclaimed at less expense than the other type, and with less uncertainty regarding the success of the project. Usually all that is needed to drain swamps of this type is improvement of the natural drainage lines and the addition of artificial channels sufficiently large to take care of the run-off during the wet seasons.

The reclamation of wet lands of the overflow type involves a study of the rivers causing the overflow before protective measures can be undertaken intelligently. It is necessary to have records of flow extending over a series of years in order that the maximum discharge can be determined. When this is known, it is necessary to build levees of sufficient height and strength to withstand this maximum flow. As the building of the levees closes the natural drainage channels of the land protected, it is also necessary to construct artificial channels which lead either to reservoirs from which the run-off is pumped during high water or else to the lower end of the district, which is left open. Therefore it is easily seen that the reclamation of lands of this type involves greater expense and a higher order of engineering ability.

It is difficult to determine the actual cost of reclaiming the wet areas in the past, as much of the work done was inadequate to drain the lands properly and consequently further work was necessary to complete the drainage, and, as this work was done in a haphazard way, the total expense was greater than it should have been. Again, many of the drainage ditches have not been properly kept up, so it is difficult to say whether the cost given represents the complete reclamation of the land. The same thing is true of the levee systems. In the lower Mississippi Valley it is customary to leave the lower end of the districts open so that the interior drainage may have a gravity outlet, but in the upper valley, where the areas are much smaller, the districts are entirely closed, making pumping necessary during certain seasons, to properly care for the interior drainage and upland drainage adjacent. As many of the northern districts have either no pumping plants or inadequate ones, the result is that during periods of high water the protected land is more or less wet and so reclamation can not be considered complete. In the reclamation of both types of swamp, small yearly charges for maintenance are necessary in addition to the first cost.

With the foregoing limitations, examples of cost and result are given, which were obtained for the most part from engineers and landowners directly interested.

WET LANDS DUE TO DEFECTIVE NATURAL DRAINAGE.

Indiana.—Twenty-three thousand acres have been reclaimed in Morgan County at a cost of $4 per acre.

In 1900 a tract of 7,200 acres, adjacent to Kankakee River in La Porte County, was bought for $21 per acre. The cost of straightening the river channel and to tile draining brought the cost up to $55. The land is now selling for $100 and upward. As the Kankakee channel was not enlarged sufficiently to care for the maximum discharge, the land is overflowed in the spring and hence reclamation can not be considered complete.

Illinois.—In 1885, 35,000 acres of land in Mason and Tazewell counties were drained. Previous to drainage the land was worth $10 to $15 per acre, and eighteen months after the ditches were completed it was worth $50 to $60.

Three thousand five hundred acres have been drained in Champaign County at a cost of $5 per acre, with an increase in value of $75 for land fully reclaimed and $5 to $25 for partially reclaimed land.

In Whiteside County 28,000 acres have been drained at an average cost of $7 per acre, with an increase in value of $25 to $50.

In Bureau and Henry counties 33,000 acres have recently been reclaimed at a total cost of $420,000, or an average cost of $13 per acre. The 33,000 acres comprised land varying from permanent swamp to land wet only during rainy seasons. The swamp comprised one-fourth of the area and was assessed $10 per acre. This swamp land had no agricultural value, but was held at $25 for speculative purposes. The increase in value has been $30, exclusive of the cost of reclamation.

J. A. Harman, an Illinois engineer of wide experience in drainage, states:

> The cost of drainage of Illinois lands has varied greatly. On the flat prairie lands, where no water is to be cared for except that which falls directly upon the lands in the drainage district, from $3 to $5 per acre has been found sufficient to provide a drainage system of main ditches and $6 to $12 per acre additional for complete tile drainage. Where it is necessary to straighten streams of any considerable magnitude the cost ranges from $10 to $20.

Minnesota.—The state drainage engineer states that 3,000,000 acres have been drained in Minnesota at an average cost of $1.50 per acre, exclusive of tile drainage, which would cost $6 to $10 per acre additional. He cites an instance where land was drained in 1906, and in 1908 produced celery which gave a net return of $1,500 per acre.

Iowa.—Twenty-two thousand acres in Calhoun County were partially drained at a cost of $3 per acre, with the result of doubling the value of the land.

New York.—Thirty thousand acres in Conawango swamp were drained at a cost of $2.50 per acre. Previous to drainage the land was worth from $2 to $5, but after drainage was valued at $30 and upward.

South Carolina.—The sanitary and drainage commission of Charleston County reclaimed 75,000 acres of swamp in that county at a cost of approximately $1.50 per acre. The Secretary of the commission, Hon. James Cosgrove, states that the land was assessed at $2 per acre prior to drainage, but has now increased so in value that some of it is held at $250 per acre. Regarding the improvement to health, he quotes a letter from the A. C. Truxbury Lumber Company, as follows:

> We are in receipt of your letter of the 16th instant asking for our experience relative to the health of our employees, and in reply we wish to say that when we first decided to locate in Charleston and were looking for a site we were informed that the property adjoining Horlbeck's woods was considered very unhealthy, but we had faith in the work of the drainage commission and decided to erect our plant at that place. This section had always been unhealthy, so much so that it was impossible for the people to live in the vicinity. One of the first buildings which was erected was a large 20-room hotel, which was built in 1905 and has since been fully occupied by our employees, many of whom came from a different part of the country and were therefore unacclimated, but we have yet to hear of the first case of malaria at the hotel. This is also the case with all of our employees, and we are satisfied that this section is now as healthy as any in the country.

LANDS SUBJECT TO PERIODICAL OVERFLOW.

Cost for reclaiming lands of this type can be given only for the upper Mississippi Valley region, as investigations have not yet been made in the Southern States.

The result of leveeing the lands along the upper Mississippi has been to increase the value from $5 to $15 for unprotected lands to $70 to $100 for lands properly leveed and drained.

Reclaimed overflow lands on upper Mississippi River.

District.	Area.	Cost per acre.	Remarks.
	Acres.		
Drury	5,700	$18	Includes pumping plant.
Egyptian	11,000	18	No pumping plant.
Sny Island	110,000	20	No pumping plant needed.
South River	10,000	20	No pumping plant.

Along the Illinois River unprotected bottom land is worth $5 to $15, while fully reclaimed land sells for $100 and upward. Much of the land is leveed, but is not properly provided with an interior drainage system. Such land sells for $35 to $60.

Reclaimed overflow lands on Illinois River.

District.	Area.	Cost per acre.	Remarks.
	Acres.		
Big Swan	12,000	$18	No pumping plant.
Hillview	12,500	25	Includes pumping plant.
Nutwood	11,000	25	No pumping plant.
Partridge	3,000	30	Includes pumping plant.
Spring Lake	12,500	20	No pumping plant.

Mr. J. A. Harman, who was quoted previously, states:

Along the Illinois River where it is necessary to construct levees which will average from 12 to 15 feet high, drainage ditches, and pumping plants, the cost varies from $20 per acre to $50 per acre for the leeves, main drainage system, and pumping plant. In no case so far has the cost been found prohibitive; in other words, these lands, which are subject to overflow and now have no productive value, but a speculative value of $5 to $25 per acre, can well afford a drainage tax of even as much as $50 per acre, because when drained they will have a productive value equal to the best land in the Mississippi Valley.

Indiana.—The O. P. D. levee opposite Newport protects 1,400 acres of land from the Wabash overflow at a cost of $20 per acre. There is no pumping plant.

In Sullivan County land that was worth $5 to $10 before leveeing is now worth $15 to $100 per acre.

COST OF FUTURE RECLAMATION.

As the reclamation of wet lands has been shown to involve inexpensive engineering work mainly, there is no reason to doubt that the greater part of the swamp and overflow lands in the country can be reclaimed at comparatively small cost per acre. Whether the character of the soil in all cases will warrant the expense can be determined only by further investigation, but the results already accomplished show that as a rule the wet lands are exceedingly fertile.

Whether the future cost of reclamation will be substantially the same as in the past, or whether it will be less, will depend largely upon the manner of doing the work. Especially is this true regarding the overflow lands. If these lands are reclaimed by the owners of different tracts acting independently of one another and reclaiming only comparatively small tracts at a time, with a possible result that protection to one section may make conditions worse in another, there is no reason to suppose that the final cost will be lessened except as methods and machinery are improved. But if the land along a river can be treated as a unit, the work can unquestionably be done more efficiently and cheaply.

In southwestern Indiana a preliminary report was made regarding the leveeing of 91,000 acres of Wabash River overflow, and it was estimated that the cost would be $8 per acre.

In Iowa drainage is being pushed very rapidly by means of drainage districts organized under state laws, whereby the land is assessed according to the benefits derived. In these districts the maximum assessments range from $3 to $11 per acre in the various districts.

In southeastern Missouri it is estimated that 500,000 acres of swamp and overflow land can be reclaimed at a cost of $10 per acre.

Mr. J. F. Le Baron, consulting civil engineer, after making preliminary surveys of the delta lands of Louisiana for the purpose of reclaiming them for rice culture, states (Trans. Am. Soc. Civ. Eng., vol. 54):

> If this land should be taken in single sections and it should be necessary to bring the water in a long flume and pump also, with a reservoir, the cost would be $16.50 per acre, while on the other hand in those locations where no pumping would be necessary, but the land could be flooded and drained by the action of the tide, the cost would be only $2.41 per acre. Each of these cases can occur on these lands.
>
> As to the income, the opinion is unanimous among all in that district with whom the writer has conversed that these reclaimed lands would rent easily and quickly for $5 per acre up to $14, with water supplied, paid in rice.
>
> These delta lands are so much richer than the prairie lands that, measured by their productiveness, they should easily bring twice as much, to say nothing of their immediate proximity to the metropolis of the State. There is no doubt they would be worth $200 to $300 per acre for truck farming when reclaimed, as some of these lands are only 3 miles from the center of the city of New Orleans, with a population of about 340,000.

PRESENT STATUS OF DRAINAGE.

While drainage work has been carried on for years in the upper Mississippi Valley, with the result that many hundred thousand acres in that section have been drained and are now among the richest farm lands, most of the other sections of the country have seriously considered the problem only within the past few years. The most feasible method of procedure has been the organizing of drainage districts by the landowners, under the state laws, with authority to raise funds by issuing bonds secured by the lands benefited. In this way the greater part of the land has been reclaimed.

Following is a brief account of the present status of drainage in each State:

Alabama.—Practically no work is being done in this State.

Arkansas.—Considerable work is being done in St. Francis Basin and in the southwestern part of the State.

California.—The most serious problem is the reclamation of the Sacramento Valley. In this section of the State, where the soil is extremely fertile, there are approximately 1,000,000 acres of swamp land, which may be increased in years of excessive high water. For years the landowners, assisted to some extent by the State, either through district organizations or by individual effort, have endeavored to levee the Sacramento River. These projects have been undertaken independently of one another, with the result that leveeing one section of the river, particularly in the lower region, has frequently made conditions worse in another section. It is estimated that vast sums, possibly reaching $20,000,000, have been spent chiefly by the landowners in river improvement and drainage work. Owing to the great amount of mining débris or detritus that is brought down by the Feather River into the Sacramento the river bed of the latter is constantly being built up, with the accompanying effect of lowering the levees.

In 1904 and 1907 the high water flooded several of the best levees of this district and did an immense amount of damage. The latter flood holds the record as to both height of water and damage done. The loss has been estimated at $5,000,000, most of which was on account of the damage to growing crops along the lower reaches of the San Joaquin and Sacramento rivers.

After the 1904 flood a state convention was called to consider the question, and a permanent organization, known as the "River Improvement and Drainage Association of California," was perfected. Through the efforts of this association many valuable data in regard to flood problems have been collected. A board was also organized consisting of three army engineers and the state engineer, which made a careful study of the situation, resulting in a federal appropriation for a detailed survey and report. This survey is being made at the present time by the army engineers. In addition to the above the State is cooperating with the United States Geological Survey in making detail topographic maps of the Sacramento Valley, and is also cooperating in the collection of run-off data. The Sacramento River being navigable, the Federal Government has done a large amount of dredging in an endeavor to maintain a navigable channel.

Florida.—The State has created a drainage district embracing most of the Everglades, and by imposing an annual tax of 5 cents per acre has created a fund with which to reclaim the land. At present there are two dredges at work cutting channels inland from the Atlantic Ocean. No other work of any size is being done in the State.

Georgia.—Attempts were made about 1894 to drain Okefinokee Swamp, but were abandoned before completion. No work is being done at present.

Drainage has been carried on actively for years, resulting in the drainage has been carried on actively for years, resulting in the drainage of practically all the upland marshes. The work remaining is chiefly protection against river overflow.

Illinois.—The last general assembly of Illinois made a small appropriation for the beginning of surveys and studies of the overflow lands of the State, for the purpose of acquiring a knowledge of the existing conditions and the methods by which the needed improvements may best be made. In accordance with this legislation, the State Geological Survey last year began the topographic mapping of portions of the Kaskaskia, Big Muddy, and Embarras rivers, in which it cooperated with the United States Geological Survey. As a result of this cooperation a topographic map on a scale of 2,000 feet to the inch, with a contour interval of 5 feet, is being made of important sections of these streams, the larger part of the work being carried on in the Kaskaskia River valley, the map of which is now practically completed from Shelbyville to the mouth of the river.

Indiana.—As in Illinois, drainage work has been carried on in Indiana for years, resulting in the drainage of the upland marshes. The work remaining is chiefly protection against the overflow of Wabash, White, and Kankakee rivers, but practically nothing is being done. Along the Kankakee River the problem has changed from that of draining marsh lands to protection against overflow.

Iowa.—Although drainage has not been carried on as long in Iowa as in Illinois and Indiana, it is being pushed very rapidly at present, with the result that the swamp lands are being rapidly drained.

Louisiana.—Beyond building levees along the Mississippi, little work has been done until recently. Now, however, a number of individuals have acquired large tracts of swamp land and are actively pushing the work of reclamation. The Manufacturers Record of June 18, 1908, describes approximately 320,000 acres that are being reclaimed.

Michigan.—In the Southern Peninsula drainage is being actively carried on, with the result that thousands of acres of the richest land have been reclaimed. The Northern Peninsula, however, is still heavily wooded, and until cleared there will be little drainage work undertaken.

Minnesota.—The State owns approximately 2,500,000 acres of wet land, for the drainage of which the legislature has appropriated $50,000 per year, and created a drainage commission, consisting of the governor, state auditor, and secretary of state. Up to 1906 the State had spent $317,000. The owners of the remainder of the swamps are actively engaged in draining them, with the result that the state drainage engineer estimates that all the lands will be drained in fifteen years at the present rate of progress. Provision was made by the Nelson Act of 1889 for the settlement by homesteaders of the ceded Chippewa lands of northern Minnesota, comprising an area of over 5,000 square miles. The settlement of these lands ceased immediately after the occupation of the high portions, as the remainder was almost entirely swamp. Congress on June 21, 1906, authorized the Secretary of the Interior to make a drainage survey of the lands in this area which remained unsold and which were wet or swampy in character, with a view to determining what portion thereof might be profitably and economically reclaimed by drainage. This survey has just been completed under the direction of the Director of the United States Geological Survey, and the results will be reported to Congress during the winter. The report for the Mud Lake district within this area has been completed and is included in Document 607, House of Representatives, Fifty-ninth Congress, second session, and is in sufficient detail to permit immediate construction work should Congress consider this step advisable.

Mississippi.—The levee along the Mississippi River is now practically completed. It is estimated that within the next two years this great work will be accomplished and will prevent in the future all overflows of the Yazoo Delta from this source. There is great activity in various sections of the State looking to the drainage of the very fertile delta lands. An act was passed by the legislature of the State on March 2, 1908, creating the Tallahatchie drainage district, incorporating the Tallahatchie drainage commission, and authorizing the governor to appoint the members thereof. This commission was given the right of eminent domain and empowered to issue bonds, levy and collect taxes for drainage construction, and enter into cooperation with the United States Government for making topographic surveys and maps of said district. Cooperation between the governor of Mississippi, the Tallahatchie drainage commission, and the United States Geological Survey was entered into on June 15, 1908, for the topographic mapping of this area on the scale of 2,000 feet to the inch, with a contour interval of 5 feet. Since that time active work has been in progress and about 40 per cent of the estimated area of the district (1,800 square miles) has been completed.

Missouri.—A drainage district has been formed to reclaim 500,000 acres of land in the southeastern part of the State. Preliminary surveys have been made, and from these it is estimated that the cost will be $5,000,000. Considerable work is being done by landowners to protect lands from overflow along the Grand, Marais des Cygnes, Tarkio, and Chariton rivers.

Nebraska.—Considerable work is being done to protect the bottom lands of the Missouri from the overflow of the tributaries coming from the bluffs.

New Jersey.—The State has made appropriations ($23,000 in 1907) for ditching the salt marshes for the purpose of exterminating the mosquitoes. Although the work enables marsh hay to be grown, diking against high tides is necessary for complete reclamation.

North Carolina.—Very little work has been done, but the State recently turned over to the control of its Geological Survey two swamps aggregating 55,000 acres. This was done for the purpose of studying the feasibility of draining them. A state drainage convention was held September 9 and 10, 1908, to stir up interest in drainage and to devise means for prosecuting the work.

North Dakota.—Preliminary surveys were made several years ago to protect thousands of acres from Red River, but no actual construction work has been done.

Oregon.—In connection with an irrigation project a considerable portion of the swamps in the vicinity of Klamath Lakes is being drained by the United States Reclamation Service.

South Carolina.—The only considerable work is the continuation of the work of the sanitary and drainage commission of Charleston County in reclaiming the swamps of that county. This commission was organized under the state laws.

South Dakota.—Several drainage districts have been organized to drain the lands in the Missouri bottoms.

Texas.—A number of drainage districts have been organized to reclaim land in the southeastern part of the State.

Virginia.—At present nothing is being done to reclaim the largest swamp area in the State—the Dismal Swamp. Capt. John G. Wallace, who has spent his life in that region, states that no steps will be taken by the owners until the route of the proposed Chesapeake and Albemarle canal is decided upon, as that will influence the drainage problem.

Wisconsin.—Drainage is being pushed fairly actively, with the result that thousands of acres have already been reclaimed.

Nothing is being done in the States omitted from the foregoing list. In most of them the swamp areas are small and scattered.

WORK OF THE UNITED STATES GEOLOGICAL SURVEY.

By two branches of the Geological Survey work is being done which has an important bearing on the reclamation of swamp lands; these are the topographic and the water-resources branches.

The work of the topographic branch consists in making a topographic map of the entire country, about 35 per cent of which has been completed. It includes a considerable portion of the swamp and overflow areas, and in addition to the actual swamp lands the higher land adjacent has been mapped, a work which is essential to a thorough understanding of the drainage problem. In connection with the surveys for mapping purposes, level lines are run giving accurate elevations, and thus much information necessary for making drainage plans is obtained.

In the water-resources branch the work consists chiefly in maintaining records of flow of the principal streams, and in this way data are being collected regarding the flow of streams that are either outlets for swamps or that overflow their bottom lands. While the information gathered is of importance in connection with the reclamation of lands of both types, it is especially valuable in the matter of leveeing overflowed lands, where the maximum discharge must be known if the reclamation is to be complete.

Besides the above work, data are being compiled relating to size and location of various swamp areas, in order that a map of each State, showing swamp conditions, may be prepared. Methods and cost of reclamation are also being studied, in order that the cost of future work of the same kind may be closely estimated.

SWAMP AND OVERFLOW LANDS.

By Dr. A. C. True,
Director of Office of Experiment Stations, U. S. Department of Agriculture.

The term "swamp and overflow lands," as commonly used, refers to lands which in their natural state are unfit for cultivation by reason of their swampy and overflowed condition. The term, as used by agriculturists, has reference to lands which can not be profitably cultivated without draining. The total area of swamp and overflow land in the United States was ascertained by a recent investigation made by the Department of Agriculture as 79,005,023 acres. These lands are classified as follows:

	Acres.
Permanent swamp land which is never fit for profitable cultivation or grazing	52, 665, 020
Lands which afford pasturage for stock, usually termed "wet grazing land"	6, 826, 019
Lands which in their natural condition are subject to periodical overflow by streams, but which at other times produce valuable crops, and called "periodically overflowed land"	14, 747, 805
Lands which may be profitably cultivated during seasons of light rainfall, but in other seasons are too wet for cultivation, and designated as "periodically swampy land"	4, 766, 179
Total	79, 005, 023

In addition to this area there are 100,000 acres of land in the arid west, once irrigated, which have been abandoned because of swampy or wet condition, and an additional 661,000 acres which are only partially productive because of their wet condition.

By the act of Congress of 1850, and subsequent acts, all federal swamp and overflowed lands were granted to the States in which they were located. With the exception of 3,200,000 acres of ceded Indian lands in the State of Minnesota and an undetermined amount in the State of Florida not yet claimed by the State, all the swamp and overflowed lands are owned by individuals, companies, or States.

The term "reclaimed land" has no exact meaning, but commonly refers to wet lands which have been wholly or partially improved by draining. Lands are frequently said to be reclaimed when relieved of water only sufficiently for pasturing purposes. By many landowners the term is applied only to lands which have been drained sufficiently to produce all kinds of cultivated crops which are adapted to the climate and soil. It is estimated that 15,889,000 acres have been reclaimed for profitable farming purposes, a large part of which lies in the Mississippi River valley.

Swamp lands lying in the prairie regions have been sufficiently drained for use as lowland pastures at a cost of $2 to $4 an acre. When the same land is drained for the production of cultivated crops the cost amounts to $15 to $20 an acre, and sometimes as high as $30 an acre.

Timbered swamp land costs 25 per cent more to drain than prairie land, and $20 an acre more to clear it of stumps and prepare it for cropping.

The 15,889,000 acres which have been converted from permanent swamp into arable land are now well-improved farms which produce a maximum yield of crops. Many of such farms are worth not less than $100 an acre, the value of the land without surface improvements being $75 an acre.

A conservative estimate of the increased value of farm lands due alone to draining is $320,000,000 over and above the cost of the operations.

Of the estimated 79,000,000 acres of swamp and overflowed land it is probable that only about 60,000,000 acres can be reclaimed and made profitable for agriculture under the present condition of labor and the demand for products. The production of lands already under cultivation is being increased. The productive value of many of the unreclaimed swamp lands, when drained, is problematical.

The cost of the construction of the larger works of drainage is decreasing, by reason of improved machines and methods of excavating large channels. The cost of such work has decreased one-half during the last fifteen years. The expense of developing the land, after the main drainage has been provided, is probably 20 per cent higher than it was fifteen years ago. A safe estimate for draining 60,000,000 acres sufficiently for good farming land is $20 an acre.

Our country could support 600,000 more families upon farms thus drained, and as many more who would be engaged in other occupations in the towns and villages which would follow the development of the land.

TENURE OF FARM LANDS.

By Prof. Le Grand Powers,
United States Census Bureau.

For the last half century at least there has been a decided tendency toward smaller individual farm holdings. The data upon which this statement is based were obtained largely from the reports of the United States Census Bureau. These reports for the various census years are on slightly different bases, and a statement of the differences may as well precede an exhibit of the facts to be gleaned from the reports of that office.

The first statistics of American farm holdings that can be compared with those of the present day were collected in 1850. In that year the United States census ascertained the number of farms and the total number of acres in farms, and thus obtained the data for determining the average size of farms. It did not, however, ascertain how many of these farms were cultivated by owners and how many by tenants, the number of separate individuals who owned farm lands, or the total number of farms of any specified area. The information collected by the census in 1860 and 1870 was identical in character with that secured in 1850.

In 1880 the census began to collect information relating to farm tenure, or the number of farms cultivated by owners and tenants, and tabulated the data so as to show the number of farms of each of a number of specified areas. The information collected and the tabulation employed in the census of 1880 have been made use of in each succeeding census, including that of 1900. In addition, the census of 1900 secured and tabulated certain information relating to the ownership of tenant farms. The data thus collected for six decennial years furnish a fair basis of ascertaining the trend in the greatest of American industries with respect to the average size of the holdings occupied and cultivated by a farm owner or farm tenant and the average size of holdings of the persons owning farm land. The facts disclosed by these census data are here discussed under a number of distinct heads, the first to be considered being that of the average holdings of those who occupy and cultivate farm land. The facts relating to this subject are reviewed under the title which follows:

DECREASED HOLDINGS OF FARMERS OR FARM CULTIVATORS.

For the purpose of summarizing these data the census arranged the States and Territories of continental United States into five divisions, to which it gave the names of North Atlantic, South Atlantic, North Central, South Central, and Western.

The census data showed that the past changes and present conditions with respect to holdings in the States which were fairly settled before 1850 were different from those changes which have taken place or the conditions which exist in the great majority of States settled in later years. To bring out the difference here noted, the North Central and South Central States were divided into two groups, here referred to as "old" and "new." The "old" North Central States are Ohio, Indiana, Illinois, Iowa, Missouri, and Michigan; the "new" North Central States—Wisconsin, Minnesota, Kansas, Nebraska, North Dakota, and South Dakota. The new South Central are Texas and Oklahoma. The data for the latter were given in the census reports under the title of Oklahoma and Indian Territory. All the other States of the South Central division are here referred to as the old South Central. The States and Territories included in the North Atlantic, South Atlantic, and old North Central and old South Central divisions are here referred to as the older group and all other States as the newer group. The data collected by the census showed that in the older group there has been a marked and almost unbroken tendency toward smaller holding by individual farm cultivators from 1850 to 1900. Every State within this group had a smaller average area of farm holdings in each census year than it had ten years previous; but combining the data of these individual States into groups, the old North Central had an average greater in 1890 than in 1880, due to the different combination of the data for the individual States. In the newer group there was a marked tendency from 1850 to 1870 toward smaller holdings, but since that time a tendency in the opposite direction. The average size of the farm holdings of individual cultivators was given for each of the two groups and the seven divisions of States here mentioned for each of the census years from 1850 to 1900:

TABLE 1.—*Average acreage of holdings of farm cultivators, 1850 to 1900.*

Groups and divisions.	1900.	1890.	1880.	1870.	1860.	1850.
United States	147.0	136.5	133.7	153.3	199.2	202.6
Older States	103.4	117.0	124.0	147.7	190.9	194.6
North Atlantic	97.5	95.3	97.7	104.3	108.1	112.6
South Atlantic	109.1	133.6	157.4	241.1	352.8	376.4
Old North Central	112.2	115.4	114.3	122.3	141.3	143.0
Old South Central	91.3	121.7	136.4	179.9	286.0	259.8
Newer States	297.7	205.8	179.6	195.7	286.6	488.4
New North Central	213.2	171.1	143.3	130.1	129.4	147.8
New South Central	324.4	223.7	208.4	301.0	590.9	942.5
Western	393.5	324.1	312.9	336.4	366.9	694.9

FARMS OF SPECIFIED AREA.

Mention has been made of the fact that since 1880 the census has so tabulated its data relating to farms and farm area as to disclose the number of farms of specified area. The data thus secured were given for the United States and for the two general groups mentioned in the following table:

TABLE 2.—*Number of farms of specified area, 1880 to 1900.*

Area in acres.	United States.			Older States.			Newer States.		
	1900.	1890.	1880.	1900.	1890.	1880.	1900.	1890.	1880.
Under 10	233,697	150,194	139,241	198,058	135,979	127,219	35,639	14,215	12,022
10 and under 20	406,641	265,550	254,749	352,193	237,525	227,067	54,448	28,025	27,682
20 and under 50	1,257,496	902,777	781,574	1,047,060	778,134	684,394	210,436	124,643	97,180
50 and under 100	1,366,038	1,121,485	1,032,810	1,096,239	928,477	874,573	269,799	193,008	158,237
100 and under 500	1,290,282	2,008,694	1,695,983	1,590,818	1,408,227	1,309,602	799,464	600,467	386,381
500 and under 1,000	102,526	84,395	75,972	44,699	64,674	61,197	57,927	29,721	14,775
Over 1,000	47,160	31,546	28,578	13,094	17,541	20,857	34,066	14,005	7,721

In the compilation of the tables no account was taken of a certain small number of farms reported in 1900 which contained less than 3 acres. They were omitted as being of a character not included in the earlier census reports and their inclusion would make the figures not strictly comparable for the several years.

In the older group there was a continued and unbroken increase in the number of farms containing less than 500 acres and a corresponding decrease in the number of farms of greater area. The increase in the average size of farms shown for this group in Table 1 was, therefore, caused principally by a breaking up of the larger farms of the earlier years and the substitution of smaller ones in the later. At the time of their settlement there was the same tendency in the older States to acquire large holdings that is to be witnessed in the newer States at the present time. Then, as now, men who obtained land for nothing or for a nominal consideration secured all they could without regard to the area that could profitably be utilized by them for agricultural purposes. Later the holdings thus obtained must be adjusted to the area that can most economically be cultivated by the individual farmer. In the older group this has tended for fifty years to be of smaller and smaller area. Time alone can tell whether such will be the tendency in the newer group. All available information leads, however, to the conclusion that the census of 1910 will disclose a marked tendency in the newer groups of the same character as the one shown in Table 2 for the older group.

OWNERSHIP OF AGRICULTURAL LAND.

The Twelfth Census was the first to collect data relating to the ownership of rented farm land, although the information secured was not sufficiently complete to establish definitely the total number of individuals owning farm land and thus the average size of the holdings of such owners; yet it suffices for the student of the subject to establish that number and that area within narrow limits for correctness. Well-known facts relating to agricultural lands and agricultural holdings in 1850 enable the student to secure the same data for the date mentioned within narrow limits of accuracy. The comparison of the available data throws much light upon the question: Has the title to American farm land tended in the last fifty years to pass to a fewer or larger relative number of individual owners?

In 1848 Gov. John Young, in his message to the New York legislature treating of the legislation needed to enforce the provisions of the third constitution of that State, adopted in 1846, forbidding the longer continuance of the feudal tenure of agricultural land, estimated that the manorial holdings in New York aggregated 1,800,000 acres, and that 260,000 people were residing on such holdings. These 1,800,000 acres were owned by relatively few proprietors. The number of separate farms on this area could not have been less than 30,000 and may have exceeded 40,000, provided the estimates of Governor Young concerning the population residing upon the same were correct; and the number of farm owners in the State was less than the number of farms by not less than 30,000, and it may have been less by over 40,000. The foregoing figures assume that the great number of tenant farms in New York in 1850 other than those held in feudal or manorial tenure were occupied by the children of their owners. Making the same exception for the older States previously mentioned, and combining the statement of Governor Young with the census returns of the number of individual farms, the conclusion is reached that the number of persons residing in the older States and owning farm land in 1850 was not more than 1,370,000, and it may not have been over 1,350,000; and the area owned by each averaged not less than 200, and that average may have been as great as 203.2 acres. In the newer States in 1850 the census reported only 39,244 farms, with an average area of 488.4 acres. The number of persons owning tenant-operated farms was doubtless nearly as great, if not quite the same, as that of such farms; and hence the average area of land held by an individual owner was not less than 488 acres. Taking the country as a whole, and combining the data reviewed for the two great groups, we reach the conclusion that in 1850 the number of persons owning farm land in the United States numbered not less than 1,390,000, and may have reached 1,410,000, with an average in the one case of 211.2 acres and in the other of 208.3 acres.

Of the 5,737,372 farms in continental United States in 1900, 2,024,964 were operated by tenants and 3,712,408 by their owners. It was further ascertained that 1,257,716 different persons owned 1,934,346 tenant farms whose owners were ascertained. The number of tenant farms, the names and residences of whose owners were not ascertained, was 90,618. For the farms whose owners were ascertained, there was one owner for every 1.54 farms. Allowing the same relative number of owners for the farms with ownership not reported, the tenant farms of the United States in 1900 were owned by 1,316,516 separate persons. Of these persons a limited number were operating owned farms, and thus included in the 3,712,408 persons operating farms of their own. The number of these persons was not ascertained. It probably was not less than 10 per cent and was with equal probability not more than 20 per cent of the number of persons owning leased farm land; or in other words, was not less than 130,000 and may have reached 275,000. Allowing these numbers, we find that the number of different persons owning farm land in 1900 was not less than 4,563,000 and may have equaled 4,893,000. The average holdings of the individual owners, therefore, was not less than 171.2 nor more than 176.5 acres.

The foregoing figures may be compared with the corresponding totals for the United States in 1850 when the average owned acreage of farm land was not less than 208.3 and may have equaled 211.2 acres. In spite of the enormous holdings of a few owners in the newer States, some of which holdings are over 1,000,000 acres, the general movement of agricultural land is not only to be cultivated in smaller holdings but is to be owned in smaller parcels.

The data secured do not admit of satisfactory analyses along the same lines for the several groups of States, owing to the fact that some land located in one State or group of States is owned in other States. Allowing somewhat for this fact, the data obtained lead to the conclusion that in 1900 the 4,317,243 farms of the older group of States were owned by not less than 3,550,000 and by not to exceed 3,700,000 persons. This would give the average area owned by an individual of not less than 120 nor more than 125 acres, as compared with the average in 1850 of 200 to 203.2 acres. The area of land owned by an individual capitalist has, therefore, decreased in these older States almost as much as has the area tilled by the average farmer.

CAUSES OF TENDENCY TO DECREASE FARM HOLDINGS.

The principal tendency to decrease farm holdings is social in its origin. The abolition of slavery changed the status of a great army of farm toilers; men who once were slaves, if retained on the farm, must be owners, tenants, or hired laborers. Since emancipation there has been a social movement among former slaves which has elevated a great portion of them and of their descendants, and they have become farm tenants. The small capital and lack of skill on the part of these former slaves, as well as the absence of any large amount of possible hired labor, makes these former slaves occupiers of small farms, and their rise to tenancy becomes a most potent factor toward lessening average farm holdings.

A change in the average status of farm labor in the old Northern States has the same influence. The possibility for poor men who leave the East and go West to become owners of farms carved out of the Government land has, with the passage of years, made an increasing number of adult male farm workers unwilling longer to toil for wages on the farm. If they can not secure a farm in the Northeast as a tenant, they will leave that section of the country and drift to the West. Hired labor can not be easily secured by those who have passed the age at which they wish to engage in hard farm labor. As a result, tenant labor displaced hired labor in the North as it displaced slave labor in the South, and with the decrease of hired and slave labor and an increase of tenant labor, the number of independent farms and farmers increases and thus forces a change in the size of farm holdings for the cultivation of the soil. Within narrow limits, the factors which determine the amount of land that the average farmer cultivates under his immediate management also determine the area of the tract which the average individual capitalist will acquire and continue to own.

Whatever may have been the effect upon the production of the soil of this decrease in the size of farms cultivated by the average owner, there can be no question that the decrease and the consequent enormous increase, actual and relative, in the number of farm owners is of tremendous social significance. It measures the enormous increase of independence among the farmers and a corresponding decrease in the number of farm dependents, as can be seen by an analysis of the constituent parts of American farm population which follows.

FARM TENURE AND THE STATUS OF FARM LABOR.

The census statistics of occupations for the later census years have been taken and compiled on a basis quite different from that of 1850. As a result, no comparison can be made between the status of agricultural labor in 1850 and 1900 without making use of some estimates for the earlier year. The writer estimates on the basis of the census data for 1850 and later years that the males employed in agricultural labor on American farms in 1850 could not have been less than 3,500,000. At that time the farms numbered 1,449,073, some of which were operated by women, as has been the case in all subsequent years. Of the 1,449,073 farms, not less than 40,000 in New York alone were operated by tenants, according to the data contained in Governor Young's message in 1848, and the number may have exceeded 50,000. The total number of tenant-operated farms in the United States could not have been less than 100,000; and of 1,000 farm owners and tenants, and males over 15 years old other than owners and tenants, working on American farms, approximately 376 were farm owners, 28 farm tenants, 373 were wage-earners and children of farm parents, and 223 slaves.

In 1900 the males 15 years of age and over working for wages in continental United States numbered 8,549,739. The farms tilled in part or wholly by their owners were 3,712,408, and those tilled wholly by tenants were 2,024,964. For every 1,000 farm owners, tenants, and male workers other than owners and tenants over 15 years of age engaged on farms, there were 417 farm owners, 227 farm tenants, and 256 others, of whom substantially one-half worked for wages or for their parents.

The relative number of farm owners was greater in 1900 than in 1850; the relative number of tenants was much greater in the later than in the earlier year, and has shown a tendency to uninterrupted increase, while that of the lowest form of farm labor has shown a most marked tendency to decrease in relative importance. With slight changes in the relative condition of farm work, there has been a tendency in fifty years to substitute tenant labor for slave and hired labor, and this tendency has been a most important factor in affecting farm tenure, the average size of farm land cultivated by the individual farmer, and indirectly in increasing the relative number of persons owning farm land and in decreasing the size of land owned by the average individual landlord.

FISHERIES OF THE UNITED STATES.

By Dr. Hugh M. Smith,
Of the Bureau of Fisheries, Department of Commerce and Labor.

The following table gives the principal annual statistics regarding the fisheries of the United States:

Items.	Total.	
	Number.	Value.
Persons employed	219,534	
Vessels fishing	4,899	$9,425,723
Tonnage	97,188	
Outfit		3,443,724
Vessels transporting	2,038	4,687,891
Tonnage	92,492	
Outfit		371,466
Boats	83,800	6,040,438
Seines	5,652	893,083
Gill nets	253,228	2,449,734
Trammel nets	1,811	85,690
Pound nets, trap nets, and weirs	12,912	3,602,408
Fyke nets	60,203	360,169
Stop nets	359	22,202
Beam trawls	75	2,267
Paranzella nets	32	5,800
Wheels and slides	90	169,255
Lines		416,494
Eel pots	29,956	27,413
Lobster pots	198,130	221,561
Dredges, tongs, rakes, and hoes		400,101
Crab dredges and scrapes		11,791
Crowfoot grapples, rakes, etc. 1		13,683
Sponge apparatus		6,663
Other apparatus		94,435
Shore and accessory property		35,853,934
Cash capital		25,648,914
Total		94,254,839

The following table shows the annual amounts and value of the products of the fisheries by species:

Products.	Pounds.	Value.
Alewives	52,061.580	$473,811
Barracudas	2,194,717	53,073
Black bass	1,939,571	150,471
Bluefish	16,575,661	781,802
Bonito	1,231,094	44,893
Buffalo fish	14,534,141	340,397
Butterfish	4,184,363	138,761
Catfish	12,718,003	531,529
Cod	85,193,618	2,295,085
Crappie and strawberry bass	1,397,306	61,188
Croaker	7,032,243	142,076
Cusk	9,079,866	139,964

Products.	Pounds.	Value.
Drum, fresh-water	3,512,881	$87,941
Drum, salt-water	4,063,230	109,055
Eels	3,815,916	223,569
Flounders	18,094,317	445,698
German carp	18,942,763	442,255
Haddock	77,065,441	1,258,763
Hake	35,928,627	419,384
Halibut	15,806,776	596,806
Herring	87,846,283	728,261
Herring, lake	32,177,689	816,046
Mackerel	16,458,604	1,110,407
Menhaden	562,427,449	1,452,062
Mullet	41,747,130	709,490
Paddlefish	1,421,086	45,906
Paddlefish caviar	11,171	7,659
Perch, white	2,674,763	160,875
Perch, yellow	7,080,770	182,274
Pike perch	10,899,604	457,975
Pike and pickerel	1,451,270	79,722
Pollock	29,033,093	305,436
Pompano	910,155	61,407
Rockfish	1,896,467	63,409
Salmon	267,601,561	12,615,748
Scup	9,216,731	250,320
Sea bass	4,282,313	183,219
Shad	28,563,385	1,702,373
Sheepshead	2,634,046	68,060
Silver hake	5,549,935	37,866
Smelts	3,414,662	152,403
Snapper, red	13,763,653	418,360
Snapper, other	401,349	11,419
Spanish mackerel	3,673,846	171,974
Spot	2,023,476	65,759
Squeteague	44,783,504	1,265,507
Striped bass	4,171,758	352,042
Sturgeon	3,146,398	149,545
Sturgeon caviar	114,814	83,409
Suckers	9,538,639	196,304
Sunfish	2,088,519	52,606
Swordfish	3,311,369	205,567
Tautog	847,756	28,298
Trout	20,158,954	1,081,117
Whitefish	7,728,761	350,186
Whiting and kingfish	1,178,650	56,107
Other fish	13,651,988	313,835
Clams, hard	9,064,852	1,385,442
Clams, soft and other	8,438,510	574,002
Mussels	1,580,065	8,469
Mussel shells	51,856,430	530,098
Oysters	217,787,610	18,449,104
Oyster and other shells	19,983,845	20,706
Scallops	1,586,151	297,658
Abalone	824,948	9,155
Squid	1,370,729	27,361
Cockles, winkles, conchs, etc	93,734	13,510
Crabs	40,219,543	905,749
King crab	2,303,000	8,903
Lobster	11,898,136	1,364,721
Spiny lobster	1,133,729	46,688
Crawfish	447,664	20,992
Shrimp and prawn	17,689,539	393,696
Shrimp shells	950,000	4,390
Sponges	346,889	364,422
Terrapin and turtle	1,409,314	114,494
Oil, fish	745,162	20,047
Oil, whale	4,341,973	267,361
Oil, sea-elephant	590,625	25,000
Whalebone	176,141	722,651
Ambergris	94	16,900
Fur-seal pelts	92,364	484,649
Sea-elephant skins	5,000	600
Alligator hides	349,927	40,779
Otter skins	6,861	35,110
Seaweeds	900,320	36,387
Other products	4,545,829	129,391
Total	2,033,992,699	61,047,909

The following table summarizes the fish-cultural operations of the bureau:

Summary of distribution of fish and eggs, fiscal year 1908.

Species.	Eggs.	Fry.	Fingerlings, yearlings, and adults.	Total.
Catfish			277,601	277,601
Carp			350	350
Buffalo fish			40,500	40,500
Shad	760,000	79,316,600		80,076,600
Whitefish	139,266,000	384,480,000		523,746,000
Lake cisco	12,790,000	3,200,000		15,990,000
Chinook salmon	68,385,550	24,998,185	2,231,797	95,615,532
Silver salmon	296,000	13,420,714	57,932	13,774,646
Blueback salmon	75,000	69,883,305		69,958,305
Humpback salmon		7,185,748		7,185,748
Steelhead trout	333,725	1,123,146	59,000	1,515,871
Rainbow trout	830,000	253,650	2,713,600	3,797,250
Atlantic salmon		2,079,514	30,003	2,109,517
Landlocked salmon	190,000	441,281	151,526	782,807
Blackspotted trout	768,380	4,230,540	1,442,376	6,441,296
Loch Leven trout			55,012	55,012
Lake trout	2,734,000	25,267,078	3,182,080	31,183,158
Brook trout	1,473,400	6,307,048	3,471,292	11,251,740
Sunapee trout		191,736		191,736
Grayling	200,000	1,047,000		1,247,000
Pike			17,550	17,550
Crappie and strawberry bass			200,268	200,268
Rock bass			25,090	25,090
Warmouth bass			1,638	1,638
Small-mouth black bass		232,312	78,940	311,252
Large-mouth black bass		23,900	588,047	611,947
Bream or sunfish			202,810	202,810
Pike perch	218,725,000	193,438,000		412,163,000
Yellow perch	2,080,000	382,576,000	68,045	384,724,045
Striped bass		4,333,500		4,333,500
White perch	5,740,000	321,670,000		327,410,000
White bass			500	500
Fresh-water drum			26,000	26,000
Cod	3,000,000	235,365,000		238,365,000
Flatfish		389,642,000		389,642,000
Pollock		66,454,000		66,454,000
Tautog		794,000		794,000
Lobster		180,932,000	1,011	180,933,011
Total	457,647,055	2,398,886,257	14,922,968	2,871,456,280

In addition to the work of the United States Government, several of the States carry on independent fish-cultural operations, the results of which are summarized in the following table:

Number and species of fish planted by States conducting important fish-cultural operations.

Species.	California, 1906.	Colorado, 1905-6.	Maine, 1907.	Maryland, 1905.	Michigan, 1903.
Shad				11,667,000	
Pacific salmon	97,731,100				
Steelhead	352,000				
Landlocked salmon			575,380		
Various trouts	1,446,000	11,000,000	993,700		6,800,000
Lake trout			487,620		930,000
Grayling					200,000
Black bass					901,200
Pike perch					30,350
Yellow perch				121,591,000	
White perch				4,300,000	
Total	99,529,100	11,000,000	2,056,700	137,558,000	8,861,550

Number and species of fish planted by States conducting important fish-cultural operations—Continued.

Species.	New York, 1906.	Pennsylvania, 1906.	Oregon, 1904.	Washington, 1906.	Wisconsin, 1906.	Number planted.
Shad	400,000	3,018,000				15,085,000
Whitefish	38,225,000	36,468,000			53,780,000	128,473,000
Lake herring		39,128,000				39,128,000
Pacific salmon			22,922,334	57,650,000		178,303,434
Steelhead			143,849	4,070,450		4,566,299
Landlocked salmon						575,380
Various trouts	3,745,000	9,681,750			4,598,900	38,265,350
Lake trout	6,015,000	6,170,000			16,107,000	29,709,620
Grayling						200,000
Smelt	74,000,000	5,000,000				79,000,000
Pickerel		179,600,000				179,600,000
Muskalunge	4,983,000	176,000			800,000	5,959,000
Black bass		73,100			1,162,000	2,136,300
Pike perch	75,045,000	53,700,000			79,140,000	207,915,350
Yellow perch	515,000	64,395,000				186,501,000
White perch						4,300,000
Tomcod	30,700,000					30,700,000
Lobster	2,040,000					2,040,000
Total	235,668,000	397,409,850	23,066,183	61,720,450	155,587,900	1,132,457,733

It will be observed from the foregoing data that the fish-cultural operations of the United States are conducted on an enormous scale, incomparably greater than in any other country. Most of the more important food fishes and all of the prominent game fishes are included in those propagated by this bureau and the several States, but there are some valuable species which are not artificially propagated, owing either to technical difficulties, lack of facilities, or the apparent absence of the necessity.

Concerning the condition of the supply of many of the marine species of fishes it is difficult to give facts, owing to fluctuations which occur in such fisheries under the influence of natural conditions beyond man's control. There is some reason to believe that certain of the shore fisheries, as for cod, have been established and maintained largely, if not solely, by artificial propagation.

In the case of the anadromous fishes, such as the shad and the Pacific salmons, the data are definite. The shad fishery was undoubtedly maintained for many years by hatching operations solely, but recently the fishery has become so intense that most of the spawning run of fish are caught before they reach the spawning grounds and a sufficient supply of eggs for the hatcheries can not be obtained. This state of affairs has been largely induced by the indifference of the States, many of which throw the entire burden of maintaining the fishery upon this bureau while neglecting to pass laws which will permit its work to become effective. This is especially true when the shad have to pass through two or more States to reach the spawning grounds, inadequate and conflicting legislation between the interested States making abortive all efforts at efficient regulation. The salvation of the more important shad fisheries lies in bringing the States to a realization of their responsibilities, to the end of securing the passage and enforcement of efficient laws. If proper protection is afforded the spawning fish this bureau can again build up the fishery and maintain it, but at present the efforts are almost hopeless.

The same difficulty of conflicting legislation obtains in the Great Lakes. On Lake Erie, for instance, there are, including Canada, five several jurisdictions with ill-defined limits, and the consequence is that no regulations are effective. In this case, as with other northern boundary waters, the matter is now under consideration by an international commission.

The most important measures for the conservation of the fisheries lie in the production of a spirit of cooperation between the law-making bodies of the several States and this bureau, and it is believed that no State in which the bureau carries on fish-cultural operations should pass fishery laws without at least consulting the bureau. It would, perhaps, be well to go further and require that in case a State passes improper laws or fails to pass necessary ones, the fish-cultural operations of the Federal Government be suspended in that State until the matter is properly adjusted.

About two-fifths of the marine and fresh-water products of the United States consist of animals other than fishes, and of these the lobster is the only one which is treated by fish-cultural methods, practically all the others for various reasons being of a character to make such treatment impracticable.

Over $20,000,000 of the annual product of the fisheries is furnished by oysters, clams, mussels, and other mollusca, and sponges, which are capable of culture under private ownership. To develop these fisheries, this bureau and some of the coastwise States have long been conducting experiments and furnishing facilities, instruction, and advice, with the result that at the present time five-eighths of the entire production of oysters is derived from private beds. In those States in which oyster culture has been encouraged and developed the industry is growing, while where the natural beds are depended upon for the supply it has decreased heavily during the past 15 or 20 years. The work carried on by this bureau and the shell-fish commissions of the several States assures that this fishery, producing about $17,000,000 at first value to the fishermen and two or three times that amount ere the product reaches the consumer, is not only in no danger of failure, but is destined to future development commensurate with the growing demands of the country.

The bureau is also conducting experiments in pearl-mussel culture in the Mississippi Valley, which, it is confidently believed, will perpetuate the button industry, worth about $500,000 to the fishermen and about $6,000,000 in finished products, and which under present conditions is doomed to speedy extinction. It has also recently developed a system of sponge culture which will prevent the extinction of the sponge fishery of Florida, now producing a raw product valued at from $500,000 to $1,500,000 per year. Other works of a similar character have been completed or are now under way.

In regard to the changes in the distribution of fishes due to mining, irrigation, and drainage enterprises, and the possibility of utilizing such projects in the increase of the supply of food fishes, the bureau can give no definite information. The importance of these subjects is fully appreciated, but no investigations relating to them have been conducted. The lakes, reservoirs, and canals established in irrigation work can undoubtedly be made important local sources of food supply, but each case will have to be made the subject for special inquiry and considered on its merits. The bureau can do nothing more than theorize at this time.

The pollution of streams by sawdust, industrial wastes, and the discharge of water from mills, most of which abuses are preventable, has received some attention at the hands of this bureau, but should be the subject of further inquiry. That these pollutions do considerable injury to some of our minor fisheries is certain, and together with the results of deforestation they have ruined many streams formerly teeming with the best of our game fishes.

THE TIMBER AND STONE ACT, AND THE COMMUTATION CLAUSE OF THE HOMESTEAD ACT.

By H. H. Schwartz,
Chief of Special Agents, General Land Office.

THE TIMBER AND STONE ACT.

June 3, 1878, Congress enacted a law providing for the sale of lands chiefly valuable for timber or stone at "the minimum price of $2.50 per acre." It applied to the States of California, Oregon, Nevada, and the then Territory of Washington. The act was later extended to all of the public-land States.

I am advised that the recommendation of the Commissioner of the General Land Office that this law be enacted, and the discussions in Congress in its consideration, disclose that the act was intended to provide wood lots for settlers and preemptors upon whose lands the supply was insufficient, and timber for local use at a fair price.

In practice, however, this law has resulted in the sale of over 12,000,000 acres of valuable timber lands, of which fully 10,000,000 acres were transferred to corporate or individual timber-land investors by the entrymen. These lands brought to the people or General Government a gross sum of $30,000,000. At the date of sale they were reasonably worth $240,000,000. The profit of over $200,000,000 went not to the needy settler engaged in subduing the wilderness, but to the wealthy investors. Not over a fractional part of 1 per cent of the timber purchased from the United States under this act is held, consumed, or even cut by the men and women who made the entries.

The law requires, and each applicant makes, an oath containing among other things the following:

"That he does not apply to purchase the same on speculation, but in good faith to appropriate it to his own use and benefit; and that he has not directly or indirectly made any agreement or contract in any way or manner, with any person or persons whatever, by which the title he might acquire from the Government of the United States should inure, in whole or part, to the benefit of any person except himself."

The Supreme Court, in United States *v.* Budd (144 U. S., 154), holds that an entry and purchase made with intent to sell at an advance if the market improves, and with no intent to use the timber itself, is not a "purchase for speculation."

Up to December 1, 1908, the department assumed that the words "may be sold * * * at the minimum price of $2.50 per acre" means $2.50 per acre absolutely, as if the words "the minimum" had not been inserted.

So that since June 3, 1878, citizens and those who have declared their intention to become such have had presented to them a law under which they may lawfully enter lands worth from $2.50 up to $200 per acre, upon the following terms:

First. At $2.50 per acre.

Second. With intent to sell the same at an advance to the first buyer, and with an intent never to use the timber thereon.

With enough entrymen possessed of $500 each, or credit to borrow that amount, and a prospective buyer at a small advance, the machinery is complete for transferring title from the Government or general public to the single corporate or individual investor. The process has been automatic, and in most cases neither fraud, perjury, or false swearing is needed.

In my ten years' experience in the Government field service I have seen several heavily timbered regions suddenly go from the Government to practically single private ownership.

The process is like this:

A timber scout or estimator reports to his employers the general situation and extent of some well-timbered region. Investigation has discovered enough timber and a present or prospective market warranting more or less extensive investment. Lands already in private ownership are purchased, probably a sawmill installed, and actual operations begun. The company or investor secures estimates on the timber on each 40 acres of vacant lands. If a settler or timber and stone applicant makes final proof, he is offered a price from $100 to $500 over the cost of the land to him. At once the community—and the relatives and outside friends of the community—learns that there is a market for timber claims and that a man with $500 can practically double it in ninety days by the simple process of entering a piece of land at $2.50 and selling it at $5 or $6 per acre.

Here again the Supreme Court, in the case of United States *v.* Budd, above cited, has made plain the operation of this law. The majority of the court say one

> might rightfully go or send into that vicinity and make known generally or to individuals a willingness to buy timber land at a price in excess of that which it would cost to obtain it from the Government, and a person knowing of that offer might rightfully go to the land office and purchase a timber lot from the Government and transfer it for the stated excess without violating the act of June 3, 1878.

Since January 6, 1908, the person entering timber lands where some investor has given his notice of a willingness to buy all lands entered need not even have the $500 with which to buy, nor need he have credit upon which he may borrow that amount. The Supreme Court of the United States, in the case of United States *v.* Williamson (207 U. S., 425), decided upon the above date, holds that an entryman who has filed his sworn statement designating the particular tract he desires to purchase may, between the date of so filing and the date of actual payment—the sixty or ninety days during which he advertises his application to purchase—lawfully contract to sell or convey the land after patent issues. In other words, he may enter the lands with an intent to sell at once if he can make a profit; the corporate or individual investor may inform him that he will buy at a profit; after the entry is made, and before the applicant advances a dollar of the purchase price, entryman and prospective purchaser may contract to convey and the investor bind the bargain by depositing with entryman's attorney enough of the sale price to pay the Government for the land, and the identical money advanced on the lawful contract to sell is paid over the counter of the land office by entryman's attorney at final proof.

There is no fraud in the entryman; no risk to the investor; and a single concern may secure a wood lot of 100,000 acres in less than a year, at a profit of $1,000,000 to the corporation and at a loss of the same sum to the general public, which is the Government.

I recall a specific instance in the Susanville and Redding districts, California, where a single investor, in the course of probably three years, acquired approximately 700,000 acres of heavily timbered lands, a large amount of which was secured under the timber and stone act.

In another large operation in central Oregon trainloads of women school-teachers were shipped out from Minnesota and entered lands under the timber and stone act. A hundred citizens of Oregon made like entries. These lands were then transferred to a timber investor from Minneapolis, Minn., transfers going to him by deeds to a corporation. The articles of this incorporation were peculiar. They provided that only the president need own stock therein; its officers were composed of the president (who was the investor) and his wife and son, who were, respectively, secretary and treasurer.

During the past ten years there have been like individual operations in Montana, Idaho, Washington, and Colorado.

But if this land is worth from $10 to, say, $30 per acre for its timber, why does the entryman sell for $5? Standing alone it may be worth only $1 or $2 an acre, but as part of a large group of claims it may be worth $50 an acre. It costs money to establish logging camps, build logging roads, and erect sawmills, and find a market for the product. The owner of a single 160-acre tract could not manufacture lumber for the market. It is when the initial costs are chargeable to a large number of claims that the actual timber values appear.

There is another and controlling reason why the individual must sell, even if he has the means to hold the land as an investment. The concern owning the milling outfit or controlling the general situation may log its surrounding lands and leave him with an isolated 160 acres of timber, with no market for so small a quantity and no buyer who could thereafter log it at a profit. Also, the general system of logging is such that fire usually runs over the cut-over lands because of litter left by the loggers. That fire will destroy what few small stands of timber remain.

There are, of course, many frauds and perjuries in operations of the timber and stone lands; but they are relatively few compared to the vast number of entries made.

Of late years we have large numbers of stone entries under this act. These are usually fraudulent, with perjury involved. There is, however, no money or value loss to the Government. These stone entries are mostly in the arid and grazing regions, for lands only fit for grazing and seldom worth more than the minimum $2.50 price.

The fraud is in the oath that lands are chiefly valuable for stone. Usually the lands are more or less isolated tracts, so geographically related to the ranch of the applicant as to make it practically necessary for him to own the tract to "round out" his holdings, make it possible to fence his own land without fencing government land, secure an outlet to the open range, or some similar need.

In pursuance of a recommendation by former Commissioner Ballinger, the department, on December 1, issued new regulations requiring as to all future timber entries that the land shall be appraised for land and timber value and then sold only at such value.

THE COMMUTATION CLAUSE OF HOMESTEAD LAW.

There is no such thing as a separate and distinct law authorizing the entry of agricultural land with intent to commute. There is the general homestead law, with minor qualifications as to Indian lands. In all, however, the applicant must swear, among other things, that he takes the land in "good faith for the purpose of making a home for himself," and not for speculation or sale. And the law under which he makes his oath and original entry requires five years' residence and cultivation.

Congress, recognizing that misfortune or change of circumstances might be the lot of any settler, has provided that any homestead claimant may, after fourteen months' residence and cultivation, commute his entry—that is, purchase the land at $1.25 to $2.50 per acre.

It has been my experience and observation in ten years of field service that the commuted homestead is almost universally an entry initiated with a full intent never to make the land a home. Before the timber and stone law was extended to all public-land States the commutation clause in the homestead law was the vehicle through which timber was fraudulently acquired from the Government.

It has been my personal experience to examine solid townships in northern Wisconsin, in which practically all the even-numbered sections had been acquired under the homestead law, quite generally commutation. The timber had been cut off after patent, and yet not a single voter or inhabitant could be found in the township. The Government got $400 a quarter section for lands frequently worth from $10,000 to $20,000. More recently actual farmers have purchased these stump lands from the mill companies.

"Commutation" is the clause in the homestead law under which citizens who are not farmers or ranchers, and who have no intention of ever becoming such, enter agricultural or valuable timber lands.

While the wording of the original commutation clause required fourteen months' residence and cultivation, the department until recently held that as homestead applicants are given six months from original entry in which to establish themselves upon the land, therefore eight months' residence immediately after the expiration of this six months complied with the law as to fourteen months' residence. That construction has been given the force of actual law by the past Congress as to former entries.

Actual inspection of hundreds of commuted homesteads shows that not one in a hundred is ever occupied as a home after commutation. They become part of some large timber holding, or parcel of a cattle or sheep ranch.

As distinguished from the timber and stone entries, commuted homestead entries are quite frequently fraudulent in their inception: in that the claimant swears falsely when he or she says that the land is taken in good faith, for the purpose of making it a home, and that there is an intent to reside upon and cultivate the land.

In the bulk of cases in which homestead entries are commuted it it found that the entrymen, both at the time of entry and at the time of proof, are engaged in some business other than agricultural or grazing. They are usually merchants, professional people, school-teachers, clerks, journeymen working at trades, cow punchers, or sheep herders. Generally these lands are sold immediately after final proof. There are few commuted homesteads upon which there is residence after final proof; and it is seldom that there is further pretense of cultivation.

Since the passage of the first commutation clause in the homestead law in 1862 there have been practically 35,000,000 acres of land acquired thereunder. The Government received probably $70,000,000 for lands worth over $350,000,000 at the time title left the United States.

The average yearly acreage commuted has been approximately 600,000. It is noted, however, that in the past few years the acreage of land annually commuted has largely increased. In 1905 there was a slight excess above 1,400,000 acres sold; in 1908 the acreage had increased to 3,124,277.

This increase coincides with the closer inspection and enforcement of the public-land law. Because of the inspection, those who are "dummies" for investors in timber, or cattle, or sheep concerns, and those who have no actual intent to make homes upon the land, are now unable to give such physical presence and cultivation to the land as will permit them to make a five-year proof. As a consequence they put in eight months time on the land, and thereupon commute. At present fourteen months actual residence is required.

I have no recommendation as to what land laws shall be enacted, but it is my opinion, after years of close personal application to this subject, that if there is one need from Congress, it is that it shall provide a reasonable fund to enable the Commissioner of the General Land Office to keep in touch with the actual conditions in the field, and make proper investigations of the manner in which public-land laws are being complied with on the one hand and abused on the other. Lands valued at hundreds of millions of dollars are annually passing from the United States to private holdings. There is an appropriation of $500,000 for this year (heretofore never more than $250,000) to cover inspection and enforcement of the law in the immense area of the public-land States.

The Government is merely the people, and whatever of the public land is fit for the home of a citizen should be held until citizens establish homes thereon. The settler should have his home free and without unnecessary restriction. But, as to lands valuable only for their timber, coal, oil, gas, or other natural resources, we may well consider whether it is not equitable that the individual who seeks for himself that which now belongs to the whole people, shall not give the people value for value in the exchange. There is no method of compelling this fair exchange other than providing the executive officers charged with the enforcement of the law with sufficient men and funds to properly and efficiently transact the people's business.

SPECIAL AGENT WORK OF THE GENERAL LAND OFFICE.

This is a statement showing approximately $110,000,000 worth of public lands believed to have been fraudulently acquired. There is reasonable prospect of recovering much of this land, if prompt action is taken.

For the fiscal year ending June 30, 1908, Congress appropriated $250,000 for the protection of public lands. A like sum had been appropriated for the year ending June 30, 1907. Public land investigations, increasing public sentiment for better protection of the national resources, and extensive discussion of these matters in publications, during the past five years, have resulted in many thousands of informations being filed in the General Land Office, charging land frauds. Many thousand cases of violation of land laws have also been brought to the attention of the Government through investigations by special agents; also, special employees of the Department of Justice have furnished the General Land Office with information in important cases.

The foregoing conditions produced great congestion in the work devolving upon the land field force. The General Land Office, local offices, and field agents receive annually thousands of complaints against claims and entries under the settlement laws. Experience shows that only about one-half of these complaints are justified. The examination of such cases has been the principal field duty—to the end that the settlement claims and entries may proceed without delay. However, the great number of extensive frauds demanding immediate action and necessarily consuming months of time in investigations and subsequent attendance in court trials leave to-day over 16,000 settlement claims suspended on complaint, out of the total 32,226 cases of all kinds pending December 1, 1908. The nature of the "necessity" for prompt action in some of the larger cases is shown in United States *v.* Juanita Coal and Coke Company, and United States *v.* Utah Fuel Company, involving lands worth $2,500,000. In these two cases the evidence of the fraudulent acquisition of these lands was finally uncovered in November last. Suits were filed December 7, 1908, and the statute of limitations would have prevented suit on December 8, 1908; likewise, in the Oregon cases against C. A. Smith et al., involving timber worth about $1,000,000, the investigations were completed, and suit was filed in May, 1908, within a few weeks of six years after patent issued. Suit can not be brought against a patent six years old.

With the $250,000 appropriated for the fiscal year ending June 30, 1907, the field force investigated and disposed of practically 6,500 cases, collected from trespassers $284,470.03, recovered 390,240 acres of land of about $2,186,400 in value, and secured the conviction in criminal cases of 138 defendants.

The present reorganization of the field force and general methods of handling the investigations in relation to public lands dates practically from the beginning of the fiscal year 1907–8. The work performed and the results accomplished in protecting public lands, recovering public lands fraudulently acquired, and prosecuting parties guilty of crimes in relation thereto from July 1, 1907, to December 1, 1908 (seventeen months), will therefore be treated as a unit. The amount appropriated for carrying on the work for the seventeen months was $500,000, viz, $250,000 for the fiscal year ending June 30, 1908, and $250,000 was expended for the first five months since that date. With this expenditure of $500,000 the following results have been accomplished:

Absolute recoveries.

10,933.07 acres of patented lands recovered (including coal lands); estimated value	$824, 555. 35
618,240 acres of entered unpatented lands recovered; value	3, 547, 100. 00
Collected from timber trespassers	136, 694. 79
Fines collected	8, 597. 94

The foregoing comprise absolute recoveries to the United States of $4,516,858.08 in money value, which is $4,016,858.05 in excess of the total appropriation expended in the work. This is not, except the fines and timber trespass, money returned to the United States Treasury; but it is lands of that value restored to the public domain where the honest purchaser or settler may acquire it; and the present administration of the public-land laws is such as to prevent the recurrence of illegal acquisition. Also, the subsequent sale of the recovered coal and timber lands—now for the first time sold upon appraisal—will result in such increase in cash returns to the Treasury as will exceed the expense of recovery.

The absolute recoveries, however, constitute but a small part of the work performed and being performed. The detailed summary hereto attached shows information in the possession of the Government which may lead to the recovery of moneys and lands reasonably worth in excess of one hundred million of dollars. How effective these recoveries shall be depends upon the men and funds available for carrying on the work.

A comparison of the number of cases actually investigated in the field and reported on shows that, during the fiscal year ending June 30, 1907, 6,500 cases were examined at a total expense of $250,000, while during the seventeen months ending December 1, 1908, 28,183 cases were examined, at a total expenditure of $500,000. Taken as a whole, the work was measurably similar, and there is a consequent showing of increase in efficiency of over 100 per cent since the general reorganization of the special service.

During the past seventeen months, special agents have caused to be released from unlawful inclosure a total of 1,007,684 acres of vacant public lands. These lands were restored to settlement and the open range.

We have secured 94 convictions for violation of the public-land laws. In a large number of these cases the fines were collected, and in important cases imprisonment sentences were imposed. A tabulated statement showing details of these convictions is attached.

The field force have also examined public lands covered by rights of way, easements, and privileges granted, of which 98 were found to be either fraudulent or illegal, and adverse proceedings have been or will be instituted to free the public lands from such easements now resting thereon.

Actual investigation and examination have also been made of nine Carey Act projects, involving 199,259.18 acres. These investigations disclose projects covering 62,070.99 acres, in which the land has not been reclaimed, and in which conditions warrant action looking to the recovery of lands, either from lack of water or because lands are not desert in character. Other examinations are in progress. These do not include original examinations upon applications to select, such examinations being made by inspectors of the department.

The expectation of the General Land Office, as expressed by the commissioner to the Committee on Appropriations when considering the sundry civil bill for the year ending June 30, 1909, that an appropriation of $500,000 per year for two years would clear up the then accumulated work, will be realized.

However, the investigations of the past two years by special agents, aided by an aroused public sentiment, have produced evidence and information of wholesale and astounding frauds upon the public lands, and such cases necessarily require much time from the field force. As a result, we have of record in the special-service division of this office the 32,000 distinct cases demanding further field action, notwithstanding that during the past seventeen months there have been investigated a total of over 28,000 cases.

The magnitude of the task imposed upon the General Land Office in some of these cases will be best appreciated by example:

In a single suit to recover coal lands having a commercial value of millions of dollars it may become necessary to take the following steps:

First. Examine all of the records and correspondence in one or more of the local land offices and in the General Land Office in relation to probably 50 distinct entries of land; this examination develops the coincidence of claimants and witnesses, attorneys of record, notaries and commissioners before whom papers were executed, with a subsequent examination of probably 50 to 100 witnesses now scattered throughout the United States, and who have in one way or another been connected with the proceedings by which the Government lost title to the lands. These witnesses embrace coal experts employed by the corporations to prospect the lands, dummy entrymen, attorneys, notaries public, United States commissioners, and the various witnesses required to the different filing papers.

Second. It is necessary to examine and abstract the titles to these lands as they appear of record in the office of the recorder of deeds in the different counties.

Third. There follows the investigation of the organization and development of the corporations and holding companies who have taken over the title and who by trust deeds and mortgages endeavor to forestall recoveries by pretended purchases or incumbrances for value. This branch of the case frequently occupies months of time by men expert in real and corporate law, and frequently develops three or four companies holding titles, mortgages, trust deeds, or bonds predicated upon trust deeds, all intended simply to involve the title. In other cases subsequent transfers have proved to be bona fide.

Fourth. To the end that the value of the lands may be determined, in the event that some one of the interested corporations is able to make good its claim of innocent purchaser, and the Government is thereby driven to a judgment for damages sustained, in lieu of the recovery of the lands, it becomes necessary for men expert in coal mining and geology to make extensive field examinations.

Fifth. As these coal companies have frequently been operating from two to five years, it also becomes necessary to determine the amount of coal taken from the lands, and its value in the different situations; which may, according to the event of the suit, fix the rule of damages the Government shall recover for probably several millions of tons of coal unlawfully taken from the lands.

It will be seen that a proper presentation of the Government's case in each one of a dozen suits similar to the foregoing may well require the entire time for from three to six months of a half dozen men.

Example might also be cited of some of the more determined and persistent violators of the act to prevent unlawful occupancy of the public lands, known as the fencing law: A single case reported from Oregon involved over 85,000 acres of government land in one inclosure; in addition thereto there were a large number of fraudulent or dummy entrymen on some of the lands inclosed. If the Government expects to present such a case as this to the court or jury, with a showing which will warrant anything more than a nominal fine (which means a very nominal charge for pasturage on the public land, and the exclusion of the general community from free range), it becomes necessary, not only to show the inclosure, but to show it in detail; probably survey, chain, and subsequently plat over 100 miles of fence; investigate into the circumstances and bona fides of probably 50 to 100 entries, of one kind or another, made within the inclosure, supposedly for the benefit of the live-stock company; also interview from 50 to 100 witnesses, the dummy entrymen; the men who built the fences, to determine when they were built, and who paid for them; cow punchers, and small cattlemen, for proof that the large company controls the inclosure, and that the stock of small individuals is driven therefrom; in some cases the settlers are forcibly prevented from investigating or occupying the lands.

Again, there are conspiracy timber cases which may well take the time for from one to three months of three or four men. Along this line the land office has single cases of over 200 entries of more than 32,000 acres of land. Combinations are frequently so well organized, and so aided by defective public-land laws, as to present an almost impossible task in securing evidence or recovering lands worth hundreds of thousands of dollars. It may become necessary to assign an agent to a single conspiracy case and keep him there to the exclusion of everything else for a period of three or four months, and in certain phases of the investigation the services of other agents are required. A single timber trespass case may require a crew of men for weeks. One case investigated this year shows trespass of timber covering 7 miles of territory and timber taken of over $200,000 value. The land was unsurveyed and it became necessary to run lines and scale up this entire trespass, measuring it stump by stump. It is an old trespass, but the Government may still recover, there being no statute of limitations against a money demand.

These examples furnish indication of what the field force has done in making recoveries mentioned in the earlier part of this statement, and what now devolves upon it in successfully prosecuting the larger cases involved in the total of over 30,000 cases pending.

Following is a summary of most of the larger cases affected by charge of fraud or illegality now pending. They are here set up by State or field divisions. Details of identification and names of parties are omitted in cases under investigation for the reason that parties are entitled to such protection until investigation develops facts warranting their presentment to a proper tribunal, and on the other hand present publishing of details would generally embarrass further inquiry in a case:

Alaska.

1. Probably 500 coal claims worth at least $200 per acre on basis of 1 cent per ton	$16,000,000
2. Pending timber trespass	200,000

Arizona.

IN UNITED STATES COURT.

3. United States *v.* Grand Canyon Lime and Cement Company, to recover for timber trespass	40,000

California.

IN UNITED STATES COURT.

1. United States *v.* Hyde, Benson, et al., to recover 11,040 acres of land patented under scrip selections	110,400
2. United States *v.* English, embezzlement, indictment, amount of shortage	15,000
3 United States *v.* Dwinell et al., conspiracy, indictment, involving 1,120 acres of timber land worth	22,400
4. United States *v.* McPherrin, and 7 others, indictment, conspiracy, involving 3,840 acres of land worth	162,000

IN DEPARTMENT.

1. United States *v.* H. H. Yard et al., 200,000 acres of heavily timbered lands covered by placer location in forest reserve	5,000,000
2. United States *v.* Golden and Darby, heavily timbered lands covered by placer mining location	80,000
3. Thirty-two timber trespass cases involving	100,000

Colorado.

IN UNITED STATES COURT.

1. United States *v.* Juanita Coal and Coke Company, to recover 2,800 acres of coal lands, value $300 per acre	840,000
2. United States *v.* Utah Fuel Company, to recover 5,000 acres of coal lands valued at $300 per acre	1,500,000
3. United States *v.* New Mexico Lumber Company, to recover 8,640 acres of best timber in Colorado, value $50 per acre	432,000
4. United States *v.* Barnes et al., timber trespass	50,000

IN DEPARTMENT.

1. One group of coal entries	1,600,000
2. One group of timber land entries	860,000
3. One group of lieu land selections	3,000,000
4. Case of lands	2,000,000
5. One group of coal entries	1,200,000
6. One group of coal entries	1,280,000
7. One group of coal claims	1,000,000
8. One group of coal claims	750,000

9. One group of agricultural entries on coal lands	$4,000,000
10. One group of timber and stone entries	440,000
11. One group of timber and stone entries	200,000
12. Six timber trespass cases	335,000
13. Two cases of coal trespass, at $1 per ton	3,500,000

New Mexico.

IN UNITED STATES COURT.

1. Suits to recover 560 acres of coal lands	56,000
2. United States *v.* Coolidge et al., 640 acres of highly improved, irrigated, agricultural lands, present value over $100 per acre	64,000

IN DEPARTMENT.

1. Group of 1,120 acres of coal lands, worth $50 per acre	56,000
2. Four hundred and eighty acres in coal entries, $100 acre	48,000
3. A case of 12 coal entries for corporation, 1,920 acres, at $50 acre	96,000
4. Group of 14 desert entries, 2,240 acres, at $2.50 per acre	5,600
5. One timber trespass of 70,000,000 feet; $2 per thousand	140,000
6. One trespass case	11,050
7. Unlawful inclosure 120,000 acres	

Michigan.

IN DEPARTMENT.

1. One group of coal and timber entries of 5,400 acres, value $10 per acre	54,000
2. Fifteen timber entries	6,000
3. Two timber trespass cases	27,000

Minnesota.

IN DEPARTMENT.

1. Fourteen timber trespass cases	112,117
2. Indian reservation lands, erroneously classed swamp, timber, value	350,000

Montana.

IN UNITED STATES COURT.

1. United States *v.* B. F. Howard et al., to recover value of timbered lands entered under the mining laws	40,000
2. United States *v.* Anaconda Copper Company, timber trespass	64,934

IN DEPARTMENT.

1. United States *v.* McCune et al., trespass of 720,000 cords of wood, stumpage value	360,000
2. Eighty tracts of coal land entered under the timber and stone act, actual value $100 per acre	1,280,000
3. One lot 4,000 acres agricultural land, worth $25 per acre, acquired under the desert-land act	100,000
4. One case involving lands, worth	100,000
5. Timber trespass in Missoula district, stumpage	500,000
6. One railroad and lumber timber trespass, Missoula district	500,000
7. Timber trespass case, Billings district	50,000
8. Land conspiracy, lands at $5 per acre	100,000
9. United States *v.* Libbey Placer Mining Company, timber lands held under mining locations	250,000

Nebraska.

IN DEPARTMENT.

1. Conspiracy of 4,000 acres desert land, value $5 per acre	$20,000
2. A case of 800 acres coal lands acquired by nonmineral entry	80,000
3. A conspiracy case; 18,000 acres	90,000

Nevada.

IN UNITED STATES COURT.

1. United States *v.* Central Pacific Railway Company and Southern Pacific Railway Company, 4 suits to recover mineral lands; lands have proved value in many operating mines of over	25,000,000

IN DEPARTMENT.

1. Rhyolite Township lands, group of lands held under mining locations	375,000
2. United States *v.* Central Pacific Railway Company, to recover about 300 acres of mineral lands erroneously acquired under its grant; a very conservative commercial value is	15,000,000

Oklahoma and Kansas.

IN DEPARTMENT.

1. Nine unlawful inclosures, including 302 alleged fraudulent entries of 51,720 acres, and 66,000 acres of vacant government lands; value of entered lands	517,000

Oregon.

IN UNITED STATES COURT.

1. United States *v.* Kribs et al., to recover timber lands having commercial value of	200,000
2. United States *v.* C. A. Smith, two suits to recover timber lands having commercial value of	750,000
3. Twenty-one allied suits to cancel 47 entries of heavily timbered lands	235,000

IN DEPARTMENT.

1. Case involving 75 timber entries	200,000
2. Case involving block of pine, heavy stand. 10,000 acres	250,000
3. Two unlawful inclosures of over 140,000 acres vacant land	
4. One lot of coal entries on timber land in national forest	200,000

Utah and southern Idaho.

IN UNITED STATES COURT.

1. United States *v.* Utah Fuel Company, and Pleasant Valley Coal Company et al., suits to recover title to over 40,000 acres of coal land, at $200 per acre	8,000,000
2. Court cases to recover 22,000 acres of heavily timbered pine lands worth about $30 an acre	660,000

IN DEPARTMENT.

1. About 20,000 acres coal lands held by nonmineral entries, worth about $100 per acre	2,000,000
2. One case of 3,500 acres of coal lands	70,000
3. Unlawful inclosure of 160,000 acres of vacant lands	
4. About 800 nonmineral claims to lands valuable for coal, at $50 per acre	6,000,000
5. Four hundred and eighty-eight state selections pending for examination	

Washington and northern Idaho.

IN UNITED STATES COURT.

1. United States *v.* Flynn, to recover 160 acres of improved lands	$8,000
2. United States *v.* Multnomah Mining and Development Company, to recover 256 acres of land	10,000
3. United States *v.* Barbee, to recover 640 acres coal lands	64,000
4. United States *v.* Kettenbach et al., to recover 8,481 acres of timbered lands, worth about $20 per acre	170,000
5. United States *v.* Hope Lumber Company, timber trespass	7,000
6. United States *v.* Bunker Hill Mining Company	

IN DEPARTMENT.

1. To recover 6,000 acres timber and fruit lands in the Colville Indian Reservation, held on mining claims	300,000

Wisconsin.

1. Three timber trespass cases	20,500

Wyoming.

IN UNITED STATES COURT.

1. United States *v.* Union Pacific Railway Company, to recover 5,186 acres of coal lands, at $300 per acre	1,555,840
2. United States *v.* Hyde, Benson et al., to recover 400 acres of agricultural land, at $10 per acre	4,000

IN DEPARTMENT.

1. One timber trespass, stumpage	350,000
2. One railroad timber trespass	45,000
3. Four trespass cases, value	47,432
4. One thousand seven hundred and sixty acres unlawfully acquired	15,000
5. United States *v.* Dally et al., to recover 9,500 acres of coal land, worth $150 per acre	1,425,000
6. Lander Coal case, to recover 2,500 acres of coal land, worth $150 an acre	375,000
7. Alleged attempt to acquire 2.560 acres of coal land, worth $200 per acre, by dummy system	512,000
8. Alleged attempt to acquire 2,240 acres of coal land, worth $200 per acre, by combination	448,000

Southern States.

1. Ten timber trespass cases involving	160,000
2. Uuited States *v.* McKaskell Company	20,000
3. Florida, 5,000 acres timber land	50,000
4. Mississippi, entries	200,000
5. Agricultural entry on oil lands	20,000
Total	114,733,273

There are also set for trial and hearing 1,021 cases before local land offices, upon reports by special agents and forest officers, as follows: Alaska, 1; Oregon, 141; California, 84; Washington, 25; Montana, 227; Colorado, 77; Arizona, 41; Wyoming, 101; Nebraska, 37; Minnesota, 7; Michigan, 1; Wisconsin, 3; North Dakota, 39; South Dakota, 26; Arkansas, 47; Louisiana, 11; Idaho, 25; Utah, 6; Kansas, 13; Oklahoma, 6; New Mexico, 71; Alabama, 11; Florida, 10; and Mississippi, 8.

There are also pending in the Department of Justice and United States courts, upon reports by special agents, the following cases:

Timber trespass	161
Suits to recover lands	490
Unlawful fencing of public lands	122
Criminal cases	321
Total	1,094

These are all cases of merit to be tried. The old business accumulated on the dockets has been dismissed wherever facts warranted.

The system of handling court cases heretofore lacked proper check between the Department of the Interior and Department of Justice. There was no automatic card or record of each case to call it, and no effective order compelling whatever additional action or investigation each case demanded. To meet this situation and clear the court dockets of cases fatally defective, and ascertain what was yet required in other cases, the Secretary and Attorney-General had appointed in each court district a committee consisting of the United States attorney, a Department of Justice inspector, and a special agent of this office. This committee took up and considered each case on the court dockets or pending for suit. Cases were found of twenty years' standing; particularly in the southern jurisdictions were found many old timber-trespass cases wherein the defendants had long since disappeared. These committees recommended the dismissal of all cases wherein it was found no reasonable basis for assuming conviction or recovery could be had. As a result, there were dismissed 245 criminal cases; 71 timber-trespass civil cases; 18 cases to recover lands, and 4 fencing cases. The remaining 1,094 cases will require heavy drafts upon the time and expense of the field corps. Some of these are old cases which are now found to require additional work. Although the above cases are now in the hands of the Department of Justice, our agents must attend terms of court as witnesses; and, where additional evidence is required, the United States attorneys naturally expect agents who were familiar with a case from its inception to supply whatever further information is required.

For the Attorney-General to require his own agents to secure additional information involves the loss of time and money incident to putting an investigation into new hands not familiar with the records, facts, and witnesses. Naturally, we must remain with the case to the end.

Record of criminal cases from June 30, 1907, to June 30, 1908.

	Indictments.	Convictions.
Timber trespass	16	8
Perjury	34	8
Subornation of perjury	4	....
Conspiracy	95	6
Forgery	4	....
Securing false affidavits	8	3
Boxing trees	5	7
Unlawful inclosure	64	31
Forest fires	2	....
Misappropriations funds of United States	2	....
Total	234	63

Record of criminal cases from June 30, 1908, to December 1, 1908.

Indictments.	Found.	Convictions.	Fines.	Fines paid.	Imprisonments.
Timber trespass	21	7	$729.92	$729.92	
Conspiracy	15	14	19,550.00	6,550.00	6
Perjury	15				
Inclosure	7	14	2,003.72	1,568.02	3
Miscellaneous	21	2			1
Totals	79	37	22,283.64	8,847.94	10

The following tabulation is a summary of the unfinished work pending December 1, 1908, and given by field divisions and number of cases:

Kind of entries.	Oregon.	California-Nevada.	Washington and Northern Idaho.	Montana.	Colorado.	Arizona.	Wyoming.	Minnesota, Michigan, Wisconsin, North and South Dakota.	Missouri, Louisiana, and Arkansas.	Utah.	Oklahoma and Kansas.	New Mexico.	Florida, Alabama, and Mississippi.	Total.
Homestead	640	741	667	984	2,038	88	1,035	1,168	882	292	737	760	898	10,930
Desert	33	62	29	1,211	846	8	146	98		183		64		2,680
Mineral	6	128	77	106	2,472	192	7	1	3	66	5	45		3,108
Timber and stone	285	69	307	287	558		236	395	145	121	2	1	274	2,680
Coal	24		54	4	705	1	72	4		53		9		926
Selects	40	63	45	133	1	4	193	2,786		488		3		3,756
Miscellaneous	125	174	18	142	1,181		155	8		24	14	7	6	1,854
Timber trespass	122	81	56	116	105	64	50	330	500	44	35	57	782	2,342
Inclosure	73	66	22	548	198	60	231	116	6	24	112	171		1,627
Off. Con. Invest	9		6		8	4		1	1	5	7	3		44
Right of way, etc					349	20		880		23	84	78		1,434
All other cases	22	14	32	54	10	55		99	56	156	2			500
Criminal	83	11	12	20	150		30	8		3	14	14		345
Total	1,462	1,409	1,325	3,605	8,621	496	2,155	5,894	1,593	1,482	1,012	1,205	1,960	32,226

The question of values above mentioned is matter of opinion. Much of the coal is the very best in America; I have valued it at $150, $200, and $300 per acre. Should the Congress conclude to separate the coal from title to the surface in disposing of lands, and permit coal mining on a royalty basis of only 10 cents per ton, these lands would produce $1,000 per acre for 10-foot veins, this on a basis that 10 out of 18 tons are actually mined. Many of these lands in the States run from 15 to 25 feet in high-grade, workable coal; in exceptional cases, fields carry coal measuring 30 and 40 feet in thickness; in Alaska, there are pending coal entries upon coal measures as high as 60 feet thick clear coal in one vein.

The question of timber values varies according to market and locality. In the Smith cases, there are lands with 3,000,000 to 10,000,000 feet to the quarter, worth on the stump $2 and $6 per thousand feet, or over $200 an acre. East of the Cascades the timber runs much lighter, and the good timber land fraudulently acquired several years ago has from 1,000,000 to 3,000,000 feet a quarter section, generally, and is worth about $4 per thousand, or, about $50 per acre. None of these lands are culls. Later entries are generally of less value.

As to the value of mineral lands in Nevada, the estimate of $15,000,000 and $25,000,000 of demonstrated values is based on careful field examination by competent mining agents. The New York Engineering and Mining Journal has estimated these lands at $100,000,000. This refers to the particular lands already examined.

This is a summary of the work performed, and the task ahead of the special agents, given in such detail as the state of work will permit, and intended to show the value of the services being performed by special agents of the General Land Office.

This letter lays considerable emphasis upon the money value of the public domain and its natural resources. Important as is this feature of our work, it is second to that of preserving for home builders the lands fit for homes and aiding to the fullest extent every settler in his effort to establish himself upon the public domain. The positive instruction of Secretary Garfield to his field force is that, although agents are to use every endeavor to prevent land frauds and crimes, they must always keep in mind that their principal task is to speedily reach and investigate the complaints involving settlement rights, to the end that the honest settler be not harassed or delayed. To that end, as before stated, investigation has clear-listed over 13,000 cases since July, 1907. That work of itself has justified the wisdom of Congress in increasing the appropriation under this head. Experience shows that, with hardly an exception, agents have followed instructions and have given the settler a favorable report wherever good faith was shown and a real intent to make a home could be drawn from all the circumstances of the case. On the other hand, they have uniformly reported the facts as they found them, or understood them, without fear or favor, conscious of the sufficient support of their superior officers. Some of the agents new to the work may have made errors of judgment; and in any case where complaint is made that the agent's findings are not warranted or that his actions are not proper, independent investigation is made, or a hearing is had, to the end that no injustice be done either to the entryman or the agent.

In addition to the regular work of advancing the settlement of the public domain, it will be seen from the foregoing summary that, through the arms of the field force, officers and employees, it is necessary to recover over $100,000,000 worth of the people's property, alleged to have been illegally or fraudulently acquired by private individuals and corporations. The last Congress raised the fund for this work from $250,000 to $500,000. Some of the larger cases cover lands patented years ago, and the knowledge or information of fraud is but recent. It is really a race with the statute of limitations in many large matters. A most cursory knowledge of the necessity of immediate action, action before the statute of limitations intervenes, and witnesses die, or memory clouds, show the inadequacy of $500,000 per annum to recover a hundred million in jeopardy. There is need for $1,000,000 for this work. It will be returned tenfold in recoveries of national resources now held unlawfully by private parties.

NOTE.—March 3, 1909, Congress appropriated the $1,000,000 asked for this work.

RIGHTS ANALOGOUS TO SCRIP.

By S. W. Williams,
General Land Office.

Scrip and the rights analogous thereto mean the right to locate or exchange lands, the basis for such right usually consisting of other lands to which the party claiming the scrip had some right, but for some reason could not acquire title; or else of land in private ownership, which, under certain conditions, may be exchanged with the Government for other lands.

Scrip rights, however, are not always based upon the loss or exchange of other lands, for Congress has granted scrip in the form of bounty land warrants for military service. Akin to this is the soldier's additional homestead right granted by the act of June 8, 1872 (17 Stats., 333).

The term scrip, of course, means a writing of some sort, but in land practice it has grown to represent the right to locate land even where no actual certificate, warrant, or other paper is issued. Thus the right of a soldier or his assignee to make an additional homestead entry, or the right of the owner of lands in a national forest, under the act of June 4, 1897 (now repealed), to exchange such lands for others, is termed scrip, though in neither case was it usual for the Government to issue any certificate or other writing as evidence of such right.

In other instances, as in the case of surveyor-general scrip under the act of June 2, 1858, supreme court scrip under the act of June 22, 1860, and other cases, it was made the duty of some designated officer of the Land Department to issue the written certificate or warrant.

It may be said that it is the office of scrip to enable its owner to acquire title to public lands without the necessity of residing, settling, or making any improvements whatever upon the lands to be acquired; and the quantity of land which may be located is determined only by the quantity of scrip which can be secured. The practice of selling the public lands indiscriminately to anyone possessing the necessary money to pay the purchase price (which I may say in passing has always been grossly inadequate) was abandoned years ago, and now only those possessing certain qualifications, and generally upon conditions more or less arduous, may secure lands by the payment of money, and even then only in limited quantities.

This, together with the fact that scrip is usually transferable by a simple assignment, renders it very valuable, and an object of eager search. Its importance as a factor in the acquisition of public lands becomes at once apparent, and the effect upon the morals of the land-seeking public is equally noticeable.

Lawyers who might otherwise have become an honor to their profession have degenerated into speculative scrip dealers. Men of good standing in their communities have not hesitated to commit perjury in behalf of their friends who supposed, from a mere similarity of names, that they were entitled to certain rights. Notaries public have disgraced their seals and prostituted their office by the making of false jurats. And even the probate courts have been converted into mere machines for the production of ready-made administrators, regardless of the domicile of the parties or the locus or ownership of the rights involved.

It naturally follows that claims established in this manner will not bear investigation. In the case of mere rights, without any accompanying certificate, there is no occasion for investigation until an application is made to locate the right upon a specific tract of land. The location may fail—it frequently does—but in the meantime the locator, who may have purchased the right in good faith, has at least some color of title, and if he should remove the timber from the land, he would be liable only as an innocent trespasser and could be made to pay only the stumpage value of the timber. The land would be denuded of its timber and yet not be cleared land suitable for cultivation, and, considering the cost of the investigation, the result would be a net loss to the Government.

So many affidavits have proved false, so many forgeries have been made manifest, and so many invalid judgments rendered to "quiet title," that the Government must exercise every care possible for the protection of its interests.

Moreover, in addition to protecting itself, it is the duty of the Government to protect, as far as possible, the owners of the rights, because in many instances the identity of the real beneficiary is the only question involved.

While the difficulties encountered upon the location of rights not represented by scrip or warrants are not usually attendant upon the location of certificates which have been previously issued, it does not follow that the law is more easily administered when the right to locate is represented by a written certificate. Indeed, there is little difference whether the right is represented by a certificate or not. In the case of mere rights the difficulty is not encountered until the location is attempted, while in the case of certificates the difficulty is encountered before the warrant or scrip is issued.

In the case of surveyor-general scrip, under the act of June 2, 1858, where, as the name indicates, the right is represented by a certificate issued by the surveyor-general, most of the land claims which formed the basis of the scrip were confirmed by laws enacted prior to 1825, and many as early as 1807, while the act which granted scrip for such of these claims as could not be satisfied in place was not passed until 1858. Consequently, most of the original claimants were dead before the scrip act was passed. Their heirs or assigns had little or no knowledge of the conditions, and made no effort to obtain the benefits of the act. Notwithstanding this, hundreds of thousands of acres of the scrip were issued and delivered to persons who secured their standing as legal representatives of the confirmees through so-called probate proceedings. Of the half million and more acres of scrip so issued, it may be safely said that not one-tenth of it reached the beneficiaries intended by the law. Men of straw were appointed administrators, who either sold the claim for a nominal sum, sufficient only to defray the expenses of the probate proceedings, or who secured the scrip and sold it for its market value, converting the proceeds to their own use, no account whatever being rendered to the court, and none ever being demanded. Men of fine abilities devoted their energies to the acquisition of this scrip. The rulings of the Land Department were evaded by one means or another, and the special service of the General Land Office being then in its infancy, or not yet even in existence, the illegal traffic continued. As illustrative of the conditions and the attitude of the scrip men, I may refer to a letter written many years ago, which accidentally fell into my hands some years afterwards. In that letter the writer (a scrip dealer) informed his partner that "eternal vigilance is the price of scrip."

It was not until quite recently, when the special service of the Land Department became thoroughly effective, that an end was put to this practice. It is now more or less an open question whether the Government is liable to the real beneficiaries for the value of this scrip.

Under the forest lieu act of 1897, the right to exchange depended solely upon the ownership of land in a forest reserve. Consequently, no stone was left unturned to obtain advance information as to the creation of these reserves, in order that lands to be included therein might be acquired before the reservation became effective. Officials were bribed to furnish this information, after which every possible effort was made to acquire a title that could be exchanged, and to this end frauds were committed upon the States to induce the selection and sale of such lands.

The administration of laws which entailed such close scrutiny in the office, and such thorough investigation in the field, is necessarily expensive. It becomes necessary for the clerks employed to acquire an intimate knowledge of the laws of all the public-land States affecting in any manner the title to real estate, and the means resorted to by some of the scrip men render it necessary for the inspectors to master almost every phase of criminal law. Considering the value of the land surrendered, it would have been much less expensive if the Government had purchased the base lands for cash.

It is but proper to state that the difficulties encountered in connection with the issue and location of scrip of the classes indicated above are not usually attendant upon the indemnity selections made by railroads and the various States, owing to the fact that the Government deals directly with the railroad or the State, as the case may be, and the quantity of indemnity may be readily determined simply by a proper method of bookkeeping. Therefore, in such cases, the only question involved is the character of the lands to be located. This, of course, at times, necessitates investigations in the field to determine the character of such lands.

The quantity of indemnity to which the State is entitled under its school grant can, in no cases, be determined until all of the land in the State has been surveyed, because, until the survey is executed, it is impossible to ascertain whether or not the right of the State to the particular sections granted has been defeated. This right, of course, is affected from time to time by the creation of national forests and other reservations, and also by the settlement, by qualified persons, of unsurveyed lands. It may be said, in this connection, that, during the past fifteen years, some 6,000,000 acres of indemnity were certified to the various States, of which amount, 1,000,000 was certified during the past year.

I shall state, for the information of the commission, that the scrip rights acquired during the operation of the act of June 4, 1897, approximate 3,000,000 acres; of this quantity it is estimated that the outstanding rights, which were protected by the repeal of the act of 1897, will approximate 25,000 acres. Claims based upon deeds of reconveyance to the United States, where no selections were made prior to, and which were not protected by, the repeal by the act of 1905, are supposed to approximate 40,000 acres.

There are outstanding comparatively few surveyor-general and Supreme Court certificates, but possibly more than 2,000,000 acres are involved in the outstanding military bounty land warrants. These certificates and warrants, however, can hardly be classed as scrip at this time, because, under recent rulings of the Land Department, they may be used only in lieu of cash in the payment for lands entered under the various general laws, at $1.25 per acre; that is to say, these certificates and warrants may not be located as scrip usually is located.

Of the several kinds of personal scrip which issued under special acts of Congress there are only a few rights outstanding, some of which, however, are very valuable, owing to the fact that little limitation is imposed upon their location. Valentine and Porterfield scrip are included in this class.

Soldiers' additional homestead rights constitute, perhaps, the most important class of scrip which is outstanding. Its importance is due to the fact that it is assignable and may be located by the assignee upon any lands subject to homestead entry, no settlement, residence, or actual improvement being required. Speaking generally, the right exists where the qualified soldier made a homestead entry prior to June 22, 1874, for less than 160 acres, the amount of the additional right being the difference between the quantity originally entered by the soldier and 160 acres. The total quantity of outstanding rights, therefore, can be determined only by first ascertaining the number of entries and the quantities of land embraced therein, which were made by such soldiers prior to 1874, and, owing to the fact that many entries were made before the military service was rendered, the entry papers themselves contain no evidence whatever connecting the entryman with the subsequent soldier. This fact constitutes one of the important features of the right, and also renders the law exceedingly difficult of administration.

In the limited time allotted it is impossible to consider every phase of this subject; but one point remains which should not be passed unnoticed. The parties intended to be benefited by the scrip laws seldom if ever realize the full value of the rights granted. To use a trite figure, the men who owned the claim constituting the basis for the right, assisted by the Government, sow the seed, but the middlemen reap the harvest.

Many owners of scrip have no sense of its value, and I have heard men boast of having bought a soldier's additional right at less than one-tenth of its value. I have even heard of the purchase of a 160-acre bounty-land warrant for the sum of 50 cents. True, some of the rights are expressly made nonassignable, but even in those cases the law is evaded by the appointment of attorneys in fact, with power to locate the right and sell the land.

It will thus be seen that where scrip rights are involved, if the Government would protect its rights and those of the individuals intended to be benefited, it too must exercise eternal vigilance.

LAND CLASSIFICATION—SHOULD SURFACE BE SEPARATED?

By Fred Dennett,
Commissioner of General Land Office.

When the position of geographer of the United States, under the Department of the Treasury, was established by the act of May 20, 1785, the officer who was appointed was confronted with the proposition of, first, arranging the lands in blocks and, secondly, of securing a purchaser for them when so arranged and made capable of description. The acres were so numerous, and money needed so seriously for the debts of the United States, that it was not so much a matter of particularity as to what was sold as to finding some one who would make a bid for what was offered. There were some 1,422,000,000 acres on the market, and when an association of individuals offered $1,000,000 for as many acres in what is now the State of Ohio, they were welcomed and the deed willingly handed them.

Even in the early times, however, it was understood that there should be some knowledge obtained as to what the United States had in its public domain, and by the act of May 18, 1796, provision was made that "every surveyor shall note in his field book the true situation of all minerals, salt licks, salt springs, and mill seats which shall come to his knowledge, all water courses over which the lines he runs shall pass, and also the quality of the land." Under the law at that time the returns were filed with the surveyor-general, but by later enactment the descriptive notes, as they are called, were to be filed in the office of the register and receiver. By various subsequent enactments geological surveys of the public domain were authorized, and such surveys were made of the States of Michigan, Wisconsin, Iowa, and Nebraska and other Western Territories, but section 2406, Revised Statutes, provided that there should be no further geological surveys unless thereafter authorized by law. By the act of March 3, 1879, the office of Director of the Geological Survey of the Interior Department was established. The act provided that this officer should have direction of the geological survey and the classification of the public lands, the examination of the geological structure, mineral resources, and products of the national domain. It was held, however, by the first director that this did not give the Director of the Geological Survey the duty of classifying the public lands, to the extinction of the direction given to surveyors and their returns. In this judgment he probably was confirmed by the fact that only $100,000 was authorized for the expenses of the survey.

The records of the General Land Office show that at one time where lands were returned by the surveyor-general as mineral the same were withdrawn from all forms of disposal except under the mineral laws. This sort of withdrawal met with strenuous opposition by those desirous of securing title to lands which they alleged to be non-mineral in character, but so withdrawn, and the withdrawals were revoked by Secretary Schurz in 1880 and the practice of making suspensions, based upon the reports of deputy surveyors, discontinued.

There is no doubt but that the classification so made was inaccurate. The deputy surveyor is not a mineralogist or geologist and runs lines which are a mile apart, works for the completion of his contract and not for the exploiting of the character of the country. Local influences would be very strong and might exercise a power over him which would be to the detriment of the general service. The rough classifications were, of course, of use, but the tendency at first was to give them greater recognition than they deserved. In fact, the rough return of the deputy surveyor was contended up to within the last eighteen months as being binding on the department in a lieu selection for lands classed as agricultural, when it was a known fact that coal existed thereon, the deposits being discovered at a time subsequent to classification. It is, however, held by the department that these returns can be overcome by evidence; and to hold otherwise would be fatal.

It is a curious circumstance that the method of doing that which was recognized as a necessity when the lands were so numerous has not been improved or kept abreast of the times and pursued with greater particularity when the lands have become comparatively scarce and the necessity for classification therefore the greater.

The General Land Office issues each year a list of the "Unappropriated Public Domain of the United States," which is based upon the returns of the descriptive notes of surveyors very often made years before the publication of this document. The lands left are the "culls" and the classification, which was made of lands before they were picked over, does not fit. In some instances climatic conditions seem to have changed and at least the basic principles upon which the lands were classified are not now as they were. Methods of dry farming have made a change in the classification of that which we would have called arid lands at one time. The "brief description and character," so called, in this list, is inaccurate and misleading and there is not an intelligent understanding of that which the United States has left to offer. It was generally supposed eighteen months ago that there were but few areas left suitable for home building. During the past fiscal year, however, there have been 88,000 entries made under the homestead law and 23,000 commutation proofs accepted, a goodly percentage of which must have been perfected since that time, thus showing that the information at hand was not as perfect as a country as modern as the United States should have.

There come to the Land Office from various parts of this country and from abroad many requests for information as to our domain and the character of the land which is left. There is returned the list referred to above with a feeling that it furnishes very little that can authentically be relied upon, and the question naturally arises as to whether or not the General Land Office should not have authentic facts which would guide a would-be settler in his search for a home.

The benefits of a thorough classification would be vast even though that classification might not be conclusive for or against the government. It would give to Congress intelligent information of how to obtain the best results from the disposal of the remaining public lands of the United States; it would furnish the executive officers and their agents with a guide in attempting to follow the mandates of the legislative body; it would at least serve as a caveat to thwart those who seek to obtain unlawfully that which there are many desirous of obtaining with a full compliance with the statutes; it would be a warning that difficulties would be encountered in the acquisition of lands if sought under a law which did not embrace the lands, as classified; it would assist in the determination as to what should pass under applications under the timber and stone act. Complaints have been received from various mining districts to the effect that timber and stone applicants seek to gain possession of lands which are really mineral in character. It has been the policy of the General Land Office to watch these as carefully as possible, but the only methods of detecting the application at present are, one, by a contest instituted by an individual, and, two, after protest made, by an examination by an agent, and for the latter work there are not agents enough, but it is an undisputed fact that there are many people who would be willing to gamble $400 for 160 acres of land in the vicinity of a mineralized territory on the off-chance that at some time minerals might be found therein.

We have yet to know what the effect of the instructions recently issued concerning the purchase of timber and stone lands will be upon this situation.

Would it not be of great value to Congress, could it have submitted classified list of its lands, upon which water can be brought in some future time, to make more homes to the quarter section, so that it could consider the advisability of legislation to preserve the lands for such purpose? One of many similar instances suggests itself wherein the claimant openly asserted that he had not grown any crop upon the land he claimed as a home, and that none could ever be grown without irrigation, but he wanted the land because some day the Government would, he thought, irrigate it. When such time comes, as it will come, the object of the act of 1902 will be, to that extent, defeated. There will be but one home where Congress intended more should be built. Had the area of coal lands been ascertained, the executive officers would not be offering a record of 474,834.54 acres patented under the coal land laws, and many times that number of coal lands in private possession, obtained from the public domain. Had the timbered domain been accurately ascertained, with the character of the lands, the abuse of the commutation clause of the homestead laws, as shown in these regions, might have been stopped by Congress preventing the application of this clause to such of the public domain as presented a value in trees and not a present value in land. Laws might possibly have been enacted to fit classified areas and the lands therein, and not one law to attempt to fit all the domain alike. It has been experienced by the agents in the field that sometimes it is a severe strain on a law to make it fit all conditions, which were not appreciated or known at the time the law was passed, being enacted to cover a status known at the time and having to meet new conditions to which it was not suited, as the latter have arisen.

Out of the original 1,421,777,280 acres of the public domain, we have disposed of 1,034,903,493, leaving some 386,873,787 acres to satisfy hungry land seekers who clamor for homes. These totals exclude the estimated 368,103,680 acres in Alaska. The lands so left are naturally the poorest. Fewer acres to give away, and a greater demand for them.

In October of this year there were 4,000 160-acre farms thrown open for home seekers in the Rosebud Reservation in South Dakota. They were not free homes. There was an indebtedness to the Indians of $6 on every acre. For those 4,000 homes there were 114,769 applicants, nearly 30 people who wanted to everyone who will obtain a chance to build a home.

A great deal of the prosperity of the United States and happiness of its citizens has been due to the fact that there has been room for expansion and a place for every man. There is but one conclusion to draw from this object lesson, and that is that the few lands which are left must be put to their greatest possible use. The surface should afford a home, though tunnels honeycomb the earth beneath.

There are vast areas of land on the Pacific Coast which carry great values in their trees. Much of these areas have been sold for their tree values alone, but the soil has been purchased with the firs and spruce. Some day the sawmills will reach them and the lands will become what are called "logged-off lands." When the purchaser acquired them there was no consideration given to the value, either present or prospective, of the soil. The lands were cruised and the moneys paid for the board measure of lumber. The lands passed with the deed. There is no one living on the lands so sold. But every once and again in the woods the traveler unexpectedly sees meadow land, a farm house, and growing crops. The farmer there will have small chance of securing neighbors, even after the trees have disappeared, for the logged-off lands will be held at a price and there will not be a free home offering an opportunity for some one who would build up values on the land to take the place of the trees it has lost. Of course, ultimately the land will be used, but not as soon as it would have been if the land were open to settlement after the trees had been cut off, and a free home could have been acquired by one who has not the price to purchase the lands, but who has the brawn and willingness to force a living from the lands if he could have secured them from the public domain.

Of course there are men who like solitude. Men there are who rejoice in the fact that the "last homesteader" is moving out, for then there will be no neighbors. But it need not be argued that the greatest good is not attained where there do not live men enough to build the trails, to make the roads, and continue the work of wresting from nature the greatest returns she is willing to give.

The evils of the present practice of giving to an applicant that which he does not ostensibly seek are shown more evidently in the workings of the coal land laws, where surface rights go with the application for the coal. The question of the operation of the present law will be discussed at a later moment, and its inadequacies presented. The homesteader seeks for the farm land only. He swears that he knows of no mineral deposits within the boundaries of his farm. One instance, a sample of many, where a claimant has lived upon his farm for twenty-three years. He has slept upon his rights, in so far as filing is concerned—but that could be cured—only to find at the time of wishing to perfect proof, that below the surface there is a deposit of coal which will prevent the issuance of his patent, under the law, as it now stands. He did not and does not want the coal. He wants his home. But the law says that he must take even to the center of the earth, and can not acquire that, if workable coal be found beneath his tillable land. We are at an impasse and yet the same land could practically be utilized for the two purposes—the mine and the home.

Alaska, with its 368,021,509 remaining acres of public lands, has not been prominently brought forward in this paper. The difficulties which will present themselves in the intelligent treatment of the lands of Alaska are before us. The experience of the past should guide. We have already learned that Alaska is not a country of barren hills and waste valleys, but that there are there fruitful vales and pasture grounds. The situation in that district must be met at the outset.

These thoughts are presented for the consideration of the committee; not intended so much to be argumentative as to offer matters which are, it is hoped, worthy of attention.

PRECIOUS MINERALS ON LANDS OF THE UNITED STATES.

By EDWARD C. FINNEY,
General Land Office.

The history of the mining of precious metals in the United States, in so far as related to existing laws, may be said to have begun with the discovery of gold in California in 1849 and the influx of treasure seekers to remote localities where, because of the nonexistence of federal and state laws, the miners were of necessity compelled to devise and adopt rules governing the location and possession of mining claims. The rules adopted by the early miners, as stated by Justice Field—

> All recognized discovery, followed by appropriation as the foundation of the possessor's title * * * and they were so framed as to secure to all comers, within practical limits, absolute equality of right and privilege in working the mines.

The mining laws of the United States, which have been in force with slight modifications since 1866 and 1872, were drafted by men who not only represented the mining States in Congress but who had actual experience in mining operations. To a considerable extent these laws recognized and adopted the customs and local regulations previously adopted by miners on the ground, especially with reference to placer-mining claims. The law with reference to lode claims was probably, as suggested by Mr. Lindley in his work on mines, based upon the customs in vogue among the lead miners of Derbyshire, requiring location to be made upon a discovery upon the top or apex of the vein and permitting the locator to follow the vein on its dip, whether within or without the surface area of his location, to the intersection of the vein with vertical planes drawn downward through the parallel end lines of the location. With vein or lode claims the principal thing sought and to which the laws have been specifically directed is the vein itself, the right to acquire sufficient surface for the convenient working and development of the vein being accorded by the law. Lodes or veins were not placed by nature in straight lines or at regular intervals, and any change in existing laws should be framed to meet actual conditions and not theoretical ones.

Under existing laws of the United States, one who has discovered the apex of a vein or lode may locate a claim 1,500 feet in length along the presumed course of such vein with surface ground not exceeding 300 feet in width on each side of the line of the lode. The discoverer of a placer deposit (and the term placer has been construed by the

Interior Department and by the courts to include not only such precious minerals as placer gold but deposits like sapphires, sheet asphaltum, building stone, oil, and gas) is authorized by the law to locate 20 acres of ground surrounding his discovery, the location conforming as nearly as practicable with the United States system of public-land surveys. From two to eight individuals may, however, combine in making a location which shall not exceed in the aggregate an area of more than 20 acres for each locator, thus permitting eight locators to locate and obtain patent for 160 acres of placer ground upon one discovery and the expenditure of $500 in development and improvement for the entire claim. The law, however, does not limit the number of separate lode or placer locations which may be made by individuals or associations.

These laws were designed to and have had the effect of promoting the development of the mineral resources of the United States. The history of mining operations in newer fields being usually that placer deposits are discovered and worked first because this class of deposits can be mined more cheaply and readily by the individual miner than can minerals found in rock in place; thus in Colorado, California, and latterly in Alaska, the placer deposits were discovered and developed first, and very properly the existing laws have been exceedingly liberal in the matter of the rights of miners with respect thereto. Later, as the regions become more thickly populated and capital seeks investment in the field, the lode deposits are developed. The vast amounts of gold taken from mines of California and Alaska, the production in the last-named district having increased from about $1,000,000 in 1880 to over $19,000,000 in 1907, have largely come from placer deposits on the public domain or from lands acquired under the placer-mining laws. As an instance of the enormous wealth found in veins or lodes, may be cited the Independence mine in the Cripple Creek district in Colorado, reported to have been sold a few years ago to an English syndicate for $15,000,000, the Camp Bird mine in the Creede mining district in Colorado, and the silver mines of the Coeur d'Alenes in Idaho. Among the profitable mines of low-grade ore may be mentioned the Treadwell mine in Alaska and the Homestake mine in the Black Hills of South Dakota.

Improved methods of mining and in the reduction of the ores have already increased and will continue in the future to increase enormously the output of mineral wealth from low-grade ores. In the mineral regions prospectors are constantly searching for new deposits, and as a result discoveries are frequently made in localities where the existence of mineral was undreamed of. In fact, for many years stock men, prospectors, and the like passed over the Cripple Creek district without suspicion of the vast mineral wealth beneath their feet, but each new discovery widens the field and promotes search for the precious substances. After the discoveries of gold in the Tonopah and Goldfield districts in Nevada, the country far and near, even far north of Reno, looked as though colonies of gigantic gophers had been delving in the hillsides. Up to June 30, 1908, 1,269,614 acres have been patented under the mining laws.

However, during recent years, owing to the increasing value of timber and of water and water powers, there has been a temptation, to which many of the unscrupulous have succumbed, to seek to acquire title to nonmineral lands containing a growth of valuable timber, or to control the course of a stream or a waterfall by means of alleged mineral discoveries and locations, especially under the placer-mining law. This law, as heretofore indicated, is exceedingly liberal, the lands being disposed of at $2.50 per acre. It is an expeditious and easy way of obtaining title to the land. In one instance attempt was made to acquire title under the placer-mining laws to a tract of land 5 miles long and about 50 feet in width lying upon either side of a stream of water, the obvious purpose being to control the water, not to secure minerals. In a case that I investigated in California, one individual and his associates had more than 250,000 acres of lands within and about a national forest, covered with alleged placer-mining locations, each location being made by eight persons and notice of the location recorded upon the county records. Thereafter most of the claims were conveyed to the instigator of the scheme or to a corporation in which he was interested.

I found that these locations were, to say the least, impartially made, as they covered streams, valleys, mountain sides, and mountain tops. Nearly all of the claims were covered with a valuable growth of standing timber. In many instances I could find no evidence of any work whatever having been performed upon the locations; in other cases, the improvements consisted of log cabins erected from timber cut upon the lands. Most of the locations failed upon careful examination to disclose any placer mineral; and in not one instance were mining operations being carried on. One of these claims located along the course of a stream failed to disclose a single color of placer gold, but was found to be exceedingly valuable, because of the fall of the stream and the amount of water therein, for a power-plant site. When this claim was attacked, the owner failed to put in an appearance, and the claim was canceled on default. This case indicates the extent to which fraudulent locations may be made under existing laws. Many other instances have come to my attention where attempts have been made to acquire title to this class of lands under the placer-mining laws, and the location of mining claims has often been resorted to as a means of obtaining and holding possession of ground for townsite, business, or other purposes. It must be borne in mind that under existing laws one who has made a valid discovery and location of a mining claim is entitled to the exclusive enjoyment and possession of the land and is not required to apply for a patent or pay the United States for the land within any specified period. Thus fraudulent locations have the effect of depriving both the United States and its citizens of the use and possession of the ground covered thereby, and such claims are only set aside after long and expensive proceedings before the department or in the courts. In other cases, where the lands do contain placer deposits, the applicants, not being required by existing law to pay for the lands and make entry within any specific time, work out the deposits and abandon the lands, leaving to the United States the worthless residue. Another defect is that under existing laws notices of location are not required to be recorded in the local land offices nor in the General Land Office. They are recorded, if at all, either with the local mining district or county recorder, and the officers of the United States charged with supervision over the public lands have no positive knowledge as to the number or extent of such existing locations. With reference to the annual assessment work required by section 2324, Revised Statutes, to be performed upon mining claims, there is no penalty prescribed save the liability to relocation by others, nor is proof of the performance of this work required by law to be filed in the Land Department. The result is that the department, having no jurisdiction over the matter of annual assessment work, is unable to secure the enforcement of the evident purpose of the law that not less than $100 must be annually expended in development of each mineral location or to declare invalid locations based upon actual discoveries of valuable minerals, but upon which this assessment work is not performed.

To conclude, it is suggested that because of change in conditions, both with respect to the minerals themselves and the other products or appurtenances of the soil, the fact that there is no law requiring entry to be made within a definite period, that the maximum area of placer claims is too large, and because the law does not require the record of location notices and assessment work to be made in the Land Department there is an apparent tendency at present to attempt to acquire a control of timber land, waters, and power sites on nonmineral lands, through alleged placer locations, to monopolize the same, and to maintain possession and continue to use the same without payment to the United States of the amounts contemplated by law within a reasonable time.

PUBLIC LANDS CONTAINING DEPOSITS OF COAL.

By T. J. Butler,
General Land Office.

The act of March 3, 1873, provides for the disposal of the public lands of the United States containing valuable deposits of coal. Under its provisions every person above the age of 21 years, who is a citizen of the United States, or who has declared his intention to become such, or any association of persons each member of which is a citizen of the United States above the age of 21 years, or has declared the intention to become such, has a right to enter any quantity of vacant coal lands of the United States not otherwise appropriated or reserved, not exceeding 160 acres to such individual or 320 acres to such association of persons, upon payment of not less than $10 per acre for such lands where the same are situate more than 15 miles from any completed railroad, and not less than $20 per acre for such coal lands as shall be within 15 miles of any completed railroad, or if such association consists of not less than four persons, and shall have expended not less than $5,000 in the development of the mine, it may enter a maximum of 640 acres.

Under the present holding of the department, and of the courts, only lands that contain a deposit of coal possessing commercial value may be entered under said laws. The theory of the law is that the prospective entrymen will open up a mine such as will demonstrate the value of the land as a coal proposition. No means has been provided by the Government for ascertaining whether or not each particular legal subdivision contains a valuable deposit of coal, further than the geological deductions from known facts, such as outcrops, or mines upon veins in the vicinity of the particular tract in question, and, as in many instances, lands which contain valuable deposits of coal are valuable for agricultural purposes or for the timber they contain, great confusion has resulted in the classification of such lands.

Less than 500,000 acres of the public lands have been disposed of by the Government as coal lands and patents issued under the coal-land laws. It will be admitted that the area disposed of since the enactment of the law in 1873 is very small as compared to the entire area of public land containing valuable deposits of coal. This results from other reasons as well as from the difficulty in the classification of the lands, and is due, in a large measure, to the fact that under the present law, only 160 acres of land may be acquired from the Government by the individual, while the maximum for an association of not less than four persons is 640 acres. It is conceded that the area allowed to be acquired by entry is, as a rule, too small to justify the great expenditure required in the opening up and successful development and operation of coal mines. Those possessed of the means of developing lands of this character would not be warranted in investing the sums that would be required in such development, and the production of coal, and to place it upon the market unless they were permitted to acquire a sufficient quantity of lands as a basis of their operation to render their investment a permanent one. As a result the tendency has been for persons and associations, who make entries and acquire patents to lands under the coal-land laws, to sell the same to corporations or large companies who develop them more with a view to the financial prosperity of the operators than to the interest of the public, and as the process of equipping the mine is expensive, it would be an impracticable and unwise investment if the area permitted to be entered were so limited as to make exhaustion within a short time certain.

Frequently coal deposits appear upon the surface of the land, which, if opened up by excavation into the side of the mountain where they appear, are, at a short distance from the surface, valuable deposits, while at the surface, and for a considerable distance beneath it, by reason of disintegration, the coal is of little value; and the individual who is led by the appearance of the coal on the surface to make entry of the land on which it appears finds that he has reached the limit of the land embraced within his entry before he has removed the disintegrated and valueless coal and reached the deposit that is of actual value.

Under the present law, if the land contains a valuable deposit of coal, which may be found at a great depth beneath the surfacc, and at the same time is of great value for agricultural purposes, or for the timber it contains, the fact that it contains such a deposit of coal prevents the home seeker from acquiring the surface as a home, or the investor from developing the timber product. In sections of the public-land States there are vast areas, frequently several townships in extent, which are underlaid with valuable deposits of coal, and the surface of which is fertile and productive and of great value for agricultural purposes. A large part of these lands has been settled by actual settlers in good faith who have constructed valuable improvements, with the purpose of establishing permanent homes, but it having become known before title was earned by the settler that such coal deposits exist upon the land, the Government has been compelled to cancel these entries at great loss and injustice to the settlers, and with no gain to the Government or anyone else; or, if patent issued before the deposit became known, title to the coal deposits as well as to the surface of the land was, by the issuance of the patent, divested from the Government and vested in an individual who found it impracticable to develop the resources which his land contained. As a result, the coal field either remains undeveloped or an intended monopoly steps in and acquires from the individuals the coal rights covering the entire field, which rarely results in a development for the best interests of the public.

It also frequently occurs that lands contain such a deposit of coal as may be profitably mined, and at the same time are of greater value for agricultural purposes. Under the present law, it is not necessary that the coal deposit be of sufficient quantity and merchantable quality to render the land more valuable for coal as a present fact than for other purposes, in order to render it not subject to entry under the homestead or other agricultural laws, but it is sufficient to prevent agricultural entry if the land contains a deposit of coal possessing a commercial value. The Land Department now finds itself confronted with a situation something like this: There are now pending before the General Land Office approximately 5,000 homestead entries in support of which final proof has been submitted, and it conservatively may be estimated that an equal number of homestead entries where proof has not been made embrace lands that have been reported by the United States Geological Survey as coal lands.

As instances of this character, the coal fields of North Dakota, which to a great extent underlie a practically level or gently undulating fertile plain, and the Raton coal field in northern New Mexico may be cited. In the North Dakota fields there are many localities where mines have been opened up showing a vein of good lignite coal 6 or 8 or 10 feet in thickness. These mines frequently are located on lands 8 or 10 or as far as 16 miles from the Missouri River, and the veins of coal have not been opened between such mine and the river, but the government geologists, who have made examinations of these lands, have been compelled to classify all the lands between the river and such coal mines as coal lands for the reason that the same vein of coal, or what appears to be the same vein of coal, is visible in the banks of the river. This intervening space of from 4 or 5 to 16 miles in width is almost entirely occupied by settlers who have made entry for the land as homesteads.

Many of these homesteaders have resided upon their farms for from five to seven years; have built comfortable houses and other improvements, in some instances of a value of from $1,500 to $2,000, and cases have come under my notice where improvements valued at $3,000 and even more have been made by such homestead entrymen, with a view to obtaining title to the lands from the Government under the homestead law. The situation in the Raton coal field is quite similar. In that field the deposit of coal consists of several veins varying in thickness from a few inches to approximately 7 feet. The coal is of excellent quality, and is said to be one of the best steam-producing coals that has been discovered in the United States. These deposits are found in blanket veins, which outcrop in the side of the mountain at approximately 1,000 feet below the top of the mountain. The top of the mountain is a flat mesa from 1 to 5 or 6 miles wide, and is covered with a growth of grass sufficient to render it valuable for grazing purposes, or where under cultivation abundant crops are produced. This mesa has been taken up by homesteaders, who have established comfortable homes and a prosperous and substantial community differing from the coal fields of North Dakota, in that patent has issued, and these homesteaders have practically all received title to their lands.

While the issuance of patents protects the interests of the individual in his improvements upon the land and his right to the use of the land and the coal it contains unless fraud is shown, still the fact remains that the Government has divested itself of all title to, interest in, or control over the valuable deposits of coal which underlie the patented land. In neither of these instances can the settler be charged with actual knowledge of the coal character of the lands which he has selected. There are no outward appearances upon his land or in the immediate vicinity thereof that would charge one not a geologist, or without considerable acquaintance with geological formations, with knowledge of the presence of coal upon such lands. The settlers have gone upon the land innocently without intention of violating the law, in pursuance of the natural home-making instincts, and after having performed all that the Government requires of them under the homestead law, the Government has found itself unable to protect them in their rights to their improvements and the use of the surface of the land, as there is no provision of law whereby title to the surface of the land may be granted without granting title to all that lies beneath the surface.

Under the present land laws no provision is made whereby the Government may develop the natural resources of its own land. In order to render these resources available the Government must divest itself absolutely of all title to the land and the deposits of coal which it may contain, nor has the Government any power under which it may, after it has divested itself of the title to the land, prevent the lands from being brought under the control of a monopoly, and either withheld from development or being developed in a wasteful manner. It thus happens that interests which own lands upon which are operating coal mines in one section of the country acquire control of other coal fields and prevent the development thereof, because they deem it of financial benefit to themselves that the coal from this other field should not be placed upon the market and made available for public use. It, of course, is unfair and unjust to the community where such undeveloped coal fields lie to be compelled to purchase the product of a distant field and pay transportation expenses.

Besides all these defects in the law as it now stands there is what, from the standpoint of public policy, is greater and of more importance than any or all of them—that is, the absolute lack of provision whereby the Government can conserve its coal resources or in any manner regulate their development. Under the present law, when the Government parts with title to the land, the private parties may conduct their operations in such manner as they see fit, and may entirely exhaust the deposit if it seems best for their financial interest that they do so. They may operate their mines in such manner as to take out only the heart of the vein, which is of the very best quality, while large quantities of coal possessing utility are either permitted to remain in the ground or to waste upon the dump at the mine opening. It is a fact of common knowledge, and it is necessarily so, that under the present law this great natural resource is simply a subject of speculation, dependent upon the present exigency of opportunity for financial gain and with no concern for the future.

The development and production of coal is conducted entirely without concern as to the coal supply for the future. The result has been that in many sections of the country the coal supply already is becoming depleted, and in some cases has been exhausted and the mines abandoned. In this connection, when I say the supply has become depleted or exhausted, I do not mean as to the physical presence of the coal, but as a profitable investment the operation of the mines is not sufficient inducement to withdraw the necessary capital from other channels of trade. Under the present law, if an applicant is qualified to make a coal entry and acts in good faith and complies with the requirements of the law, he can not be refused patent, and when patent issues, under such circumstances, the Government divests itself absolutely of further control over the coal deposit or the development thereof. No matter what waste may be committed, nor to what extent the public may be deprived of the use of this great resource, the Government can not, except under its police power, interfere with the right of dominion over his property exercised by the individual.

THE DESERT LAND ACT.

By W. B. Pugh,
General Land Office.

It is difficult if not impossible to conceive that Congress, when it framed and enacted the acts of March 3, 1877, and March 3, 1891, which contain what we commonly call the law of desert-land entries, did not have in contemplation the beneficent results incident to a complete and permanent reclamation of the arid public lands as distinguished from a partial and temporary achievement in that direction. And I think it will, as it must, be conceded that such was the object and the hope of the lawmakers, for, as reformation is never of any value save as it is effectual and durable, so would reclamation of waste and desert areas be useless and unprofitable if subjugation is to be only for a time, after which the desert is to return with all its incidents. Temporary reclamation is nothing but a casual suspension of natural conditions, and without continuing means of and provision for irrigation a reclaimed desert would soon relapse into its former state of aridity and barrenness.

The law intends, and expressly demands, that as a condition precedent to the acquisition of title to desert lands, the individual who seeks the benefit of its license shall perform and prove actual and absolute reclamation of the whole area of the entered land. There is no qualification, in the language of the law, as to the extent or degree of successful achievement, but a plain and unequivocal requirement of full and complete redemption. The letter of the law does not authorize any disposition thereunder of one solitary acre of unreclaimed lands, but the Interior Department, charged with administration, has very properly construed its provisions in such manner and to such effect that, where it is satisfactorily shown that there are included scattered areas too high or too stony to admit of successful and practicable irrigation, failure to carry water onto those areas will not defeat an application for patent. By way of taking some security for the future the law has been held to require that as a means to permanent irrigation the entryman shall possess, in his own right and by an absolute title, the right to the use of water sufficient for the irrigation of all of the irrigable land included in his entry; and, by way of providing for irrefragable and indisputable evidence that the grasp of the desert has been broken and cast off, it is required that at the end of four years the entryman shall prove that he has successfully cultivated at least one-eighth part of the land he has undertaken to redeem.

Having laid this premise as to the spirit and the purpose of the law, as evidenced by the several specific provisions or constructive requirements thereof to which I have alluded, I shall now make a few suggestions as to the practical workings of the law as I have had opportunity to observe them in the field.

First. It is manifest that, apart from those evils to which the operation of every public-land law is subject, which have their origin in craft and cunning and guile, and which tend to defeat the design of the law, the administration of the desert-land law is subject to abuses which may be deemed special and peculiar. In the short space allotted to me I can only direct attention to two or three of the principal of these abuses. What seems to be a very serious evil, and one commonly met with in practice, may be ascribed to the failure of the law itself to fix and prescribe any minimum of irrigable and irrigated area, out of a total area entered, which will entitle the entryman to patent. As I have previously pointed out, the department, considering that Congress must have known and had in mind when it enacted this law that nearly every desert-land entry would embrace some small spots or parcels of ground which could not be irrigated without resort to expenditure greater than any possible value those particular parcels would possess in a reclaimed condition, has so administered the law as not to require proof of the irrigation of such small parcels. As to such included areas the only requirement of proof is that it shall be shown that reclamation is impracticable. But the department has not prescribed, and can not establish, any engineering standard by which to determine the practicability or impracticability of irrigation to which resort may be had in all cases, and must manifestly accept the statement of the claimant and his proof witnesses concerning such an alleged condition; and it is more or less obvious that the determination of what is and what is not practicable in irrigation is, as it must be, left largely to the conclusion of the claimant and those who testify in support of his claim.

The proof usually submitted in support of such a contention or conclusion is wholly nonexpert and unprofessional and is generally extremely simple and indeterminate in character and probative tendency. As a result of this want of fixed limitation and in the absence of any standard by which to measure practicability of irrigation, desert-land entries for 320 acres of land very frequently pass to patent upon proof showing reclamation of only 40 or 45 acres; and in passing it may be suggested that even this slight modicum of achievement is often of doubtful value. While serving in the field I have often had my attention directed to desert-land entries on which patents had been granted of the lands of which only a small portion had been irrigated. It required only a casual examination to create the conviction that the expenditure of some very small sum of money in addition to what had been expended, or the exercise of some greater intelligence or care in the choice of a location for the diversion dam or reservoir, would have resulted in an important increase in the irrigated area. The impression created in my mind, as the result of what I witnessed of the operation of the desert-land law, is that it is too frequently the case that the entrymen of such lands desire to secure them only for pasture for cattle, for which purpose they would provide a sufficient growth of grass without irrigation, and that reclamation is only a fiction, or perfunctory sort of process, necessarily preceding application for the legal title. It is also true that the entryman, when he comes to determine what portion of the entered lands it is practicable to irrigate, does not always have in mind the test of practicability described by the department, to which I have previously alluded, but rather refers to the state of his purse, or his willingness to make the expenditure necessary for reclamation of a larger area.

Second. The water rights relied upon are too often so precarious, or so utterly without merit, as to hardly deserve the title. Very frequently do they depend upon mere surface-water drainage, accumulated in or by a dry draw, coulee, or arroyo and conserved in a reservoir created by constructing a dam across the coulee at the place of ultimate impounding.

While appropriation of surface water is sanctioned by the laws of some of the States, it is more or less difficult, if not impossible, for the legal mind to clearly perceive how such an alleged right can possess either of the essential elements of permanency or absolutism, except and unless the entryman owns the drained area or has some contract right by which he may forever demand unobstructed flow of the surface waters. By surface waters I mean, of course, the waters resulting from rains or melting snows. If he has no such title or contract right, it seems more or less clear and certain, as a legal proposition, that, however such a right, or alleged right, may have the support of state legislation, the claimant under it can not hope to so enforce his claim against the United States, or against their grantees of the lands within the drained area, as to charge those lands with the burden of forever serving as a mere dripping pan for the benefit of his lands. On the contrary, it might seem reasonably well settled that the legal owners of such drained lands may employ them in agricultural uses or other lawful ways without regard or concern for such consequential interference with, or absorption of, the surface waters as will practically destroy the right of the alleged appropriator.

Third. As now ordered and provided by the law of most of the several States and Territories, a water right is not appurtenant to the land upon which it is employed, in the sense that it can not be severed; as a consequence, the same right is made use of for the temporary reclamation of several different tracts of public lands claimed by different entrymen, one of these exercising it only long enough to enable him to make the proof required by law, whereupon he transfers it to some other claimant, who would not otherwise be able to secure the use of water, owing to the prior appropriation and often overappropriation of all of the available water. It is a manifest consequence of this condition that there are, in many localities where this practice obtains, large areas of land appropriated under the desert-land law, for the permanent reclamation of which there is no possible source of water supply. It is a common experience to find that there are large quantities of land with whose title the Government has parted under the desert-land law and as to only a very small portion of which has the real and essential purpose of the law been secured. I may properly say that I have traveled through localities in which more or less extensive areas of lands had been disposed of under the desert-land law, and a most critical inspection failed to reveal the slightest evidence that these lands had ever received any treatment different from that to which the yet unappropriated public lands in the same localities had been subjected. Yet I had no reason to doubt, and, in fact, inquiry led to the conviction, that the letter of the law had been complied with, with perhaps some slight evasion and some slight coloring of proof. The situation I observed was simply due to the fact that the entrymen of these lands had not, at the time of original entry, entertained any purpose to permanently maintain the condition of reclamation which they might produce; acquisition of legal title had been followed by concentration of ownership and subsequent abandonment of all irrigation instrumentalities. Lapse of time and the trampling of cattle, to the pasturage of which the lands had become devoted, completely effaced all evidences of ditches and all other means or results of irrigation.

There are other evils of which I might give some illustration if my title to your further patience were greater, but those which I have tried to delineate seem to me to be the most serious, as considered apart from those which are the result of pure fraud and unscrupulous and purposeful violation of the law.

COAL FIELDS OF THE UNITED STATES.

By Marius R. Campbell and Edward W. Parker,
United States Geological Survey.

According to the estimates prepared by the U. S. Geological Survey, the area underlain by workable coal beds in the United States is 496,776 square miles. Of this total area, 480 square miles contain the entire anthracite coal fields of Pennsylvania. The bituminous coal fields are estimated to be contained in an area of 250,051 square miles. The grade of coal between bituminous and lignite, which is designated by the Geological Survey as "subbituminous," is estimated to be contained within areas aggregating 97,636 square miles, while the areas containing lignite aggregate 148,609 square miles. The coal fields are divided, for the sake of convenience in classification, into six main provinces, as follows:

1. The eastern province, containing the anthracite coal fields of Pennsylvania and the bituminous coal fields of the Appalachian region, i. e., those of western Pennsylvania, Ohio, Virginia, West Virginia, Kentucky, Tennessee, Georgia, Alabama, and small outlying areas in North Carolina.
2. The interior province, containing the bituminous coal-producing regions of Michigan, Illinois, Indiana, western Kentucky, Iowa, Kansas, Missouri, Oklahoma, Arkansas, and Texas.
3. The Gulf province, containing the lignite areas of Alabama, Mississippi, Louisiana, Arkansas, and Texas.
4. The northern Great Plains province, containing the lignite subbituminous areas of North and South Dakota, eastern Montana, and northeastern Wyoming.
5. The Rocky Mountain province, containing the bituminous and subbituminous areas of western Montana and western Wyoming, Colorado, Utah, and New Mexico.
6. The Pacific coast province, containing the areas of Washington, Oregon, and California.

During the last few years the Survey geologists have worked in all of these coal areas and have also been making careful estimates of the quantity of coal contained in the beds when mining first began. In making these estimates care has been taken to ascertain how much of the supply is easily available and how much is either not available under present mining and market conditions or is available with extreme difficulty. According to these estimates the quantity of coal contained within the known area of the United States when mining first began was 3,076,204,000,000 tons. Of this quantity a little less than two-thirds, or 1,922,979,000,000 tons, is considered as coal that is easily accessible or minable under present conditions, while slightly more than one-third, or 1,153,225,000,000 tons, is considered as non-minable under present conditions or accessible with extreme difficulty. It should be remembered, however, that the quantity of coal given above as easily accessible includes the lignites and subbituminous coals of the Western States, of which approximately 530,000,000,000 tons, while easily accessible, can not be considered available under present conditions or those which may be expected in the near future. This would reduce the original supply of easily accessible and available coal to approximately 1,400,000,000,000 tons.

The area of the different provinces and the quantity of coal contained therein when mining first began are shown in the following table:

Tonnage (short tons), by provinces and accessibility.

[Original coal supply.]

Province.	Area in square miles.	Amount easily accessible.	Amount accessible with difficulty.	Total.
Eastern	70,022	555,634,000,000	8,000,000,000	563,634,000,000
Interior	144,664	406,667,000,000	91,000,000,000	497,667,000,000
Gulf	84,300	13,045,000,000	10,045,000,000	23,090,000,000
Northern Great Plains	103,564	521,793,000,000	459,000,000,000	980,793,000,000
Rocky Mountains	92,396	414,740,000,000	574,280,000,000	989,020,000,000
Pacific coast	1,830	11,100,000,000	10,900,000,000	22,000,000,000
Total	496,776	1,922,979,000,000	1,153,225,000,000	3,076,204,000,000

The distribution of this original supply of coal, according to grades and accessibility, is shown in the following table:

Tonnage (short tons), by grades of coal and accessibility.

[Original coal supply.]

Kind of coal.	Area in square miles.	Amount easily accessible.	Amount easily accessible and available.	Amount accessible with difficulty.
Anthracite and bituminous	250,531	1,176,727,000,000	1,176,727,000,000	505,730,000,000
Subbituminous	97,636	356,707,000,000	216,252,000,000	293,450,000,000
Lignite	148,609	389,545,000,000		354,045,000,000
Total	496,776	1,922,979,000,000	1,392,979,000,000	1,153,225,000,000

The first mining of coal in a commercial way, in the United States, was in what is known as the Richmond basin, a small area in the eastern part of Virginia. Small quantities of coal had been mined here in the latter part of the eighteenth century and it was also in the latter part of the eighteenth and the beginning of the nineteenth centuries that efforts were being made to introduce anthracite coal for fuel purposes. The first actual records of the production of Virginia coal were in 1822, in which year it was reported that 54,000 tons were mined. In 1820 (two years before) 365 long tons of anthracite coal, or 1 ton for each day of the year, had been shipped to distant markets. From these small beginnings of less than a century ago the production of coal has increased until in 1907 the total output of anthracite and bituminous coal approximated 500,000,000 tons. In 1837 the total production of the United States reached, for the first time, a total exceeding 1,000,000 tons, the output being reported from 4 States only—Pennsylvania, Virginia, Kentucky, and Illinois—although Maryland also was producing a small quantity of coal at that time. In 1840 the production amounted to a little over 2,000,000 tons, the output being reported from 13 States. Ten years later, in 1850, the production amounted to 7,000,000 tons; in 1860 it was over 14,000,000 tons; in 1870 over 33,000,000 tons; in 1880 over 70,000,000 tons; in 1890 it approximated 160,000,000 tons; in 1900 it was nearly 270,000,000 tons; and in 1907 it was 480,000,000 tons. The aggregate production to the close of 1907 has amounted to 6,865,097,567 short tons.

Up to the close of 1845 the total production of coal in the United States was 27,700,000 short tons, and since that time the drain on the supply has practically doubled with each decade. The total production to 1845 and decennially since that time has been as follows:

	Short tons.
Up to 1845	27, 677, 214
1846–1855	83, 417, 827
1856–1865	173, 795, 014
1866–1875	419, 425, 104
1876–1885	847, 760, 319
1886–1895	1, 586, 098, 641
1896–1905	2, 832, 402, 746
1906–1907	894, 520, 702
Total	6, 865, 097, 567

It is estimated that for every ton of coal mined and sold, half a ton is lost or wasted, so that the total production of 6,865,097,567 short tons to the close of 1907 represents an exhaustion of 10,200,-000,000 tons, or 0.3 per cent of the total original supply, or 0.7 per cent of the coal which is easily accessible and available under the present conditions. The total supply of easily accessible and now available coal left in the ground at the close of 1907 was 1,382,780,-000,000 short tons.

Accompanying this statement two charts are presented, one showing the production of coal annually from 1846 to 1907, the other illustrating the average annual production by progressive ten-year periods for the same length of time, the latter chart having been prepared in order to eliminate minor variations due to abnormal conditions. The average annual increase in coal production figured from the average of progressive decades shown on the second diagram is 7.36 per cent, and for the last five progressive decades—1894–1903 to 1898–1907—the rate of increase has been above that average.

DURATION OF SUPPLY.

The total reserve of easily accessible and now available coal is estimated at 1,382,780,000,000 tons. The assumption that a constant output has been reached would be utterly unwarranted. On the other hand, the adoption of the flat rate of annual increase of 7.36 per cent would involve the improbable assumption that the marvelous record of the past and present will be maintained in the future and the production would continue to approximately double every decade. Using the waste allowance, on the basis of this constant rate of increase in production, the 1,382,780,000,000 tons available at the close of 1907 would be exhausted in one hundred and seven years, or by 2015 A. D. Against the use of the flat rate of increase it may well be contended that just as the rate of increase in population tends to diminish, so this rapid increase in per capita consumption of coal can not persist, and a constant annual production will be reached. However, the figures set fifty years ago by statisticians for the probable constant annual production of coal in England have already been exceeded by over 160 per cent.

Mr. Henry Gannett has made an estimate based upon a decreasing rate of increase calculated from twenty-year averages of production. The use of ten-year averages is regarded as unsatisfactory for the reason that one of the decades may consist mainly of a period of prosperity, while the preceding and succeeding decades contain periods of business depression. The twenty-year period, however, is sufficiently long to include a period of prosperity with one of business depression. Taking the four twenty-year periods since 1828, three rates of increase are obtained which show a rapid decrease. The hyperbolic curve computed from these successive rates of increase will indicate the constantly diminishing rate of increase for the successive twenty-year periods. The result obtained by this method is that the easily accessible and available coal will be exhausted about the year 2027, and all coal by the middle of that century. It is recognized that the data upon which this curve has been constructed are few and the curve correspondingly weak. However, in the above estimate all of the data have been given which it is possible to use, and this estimate is believed to represent the best use that can be made of the data at hand.

Inasmuch as America leads the world not only in present production of coal, but also apparently possesses the greatest reserve and certainly is mining coal at much lower cost than any other country, the obvious tendency will be for European countries to look more and more to the United States for their coal supply. Therefore, while our present coal production and consumption are practically equivalent, the export of coal, unless prohibited by federal legislation, must eventually become a factor and increase the coal production in the United States beyond the demands of home consumption. On the other hand, powerful influences will come to bear upon coal production, which favor lengthening the life of the supply. Thus it is to be hoped that with more improved methods in the utilization of coal the increased efficiency per unit may act as a factor in reducing coal consumption, and improved mining methods should likewise decrease the waste percentage. The increased utilization of water power should also tend to decrease coal consumption. Again, as soon as the end appears in sight prices will rise and production diminish, and that progressively. This interference with the law of decreasing increase produced by growing scarcity will, of course, prolong the life of our coal reserves, but at the same time will greatly hamper our industries that depend on this fuel.

With so many indeterminate factors whose importance is realized but can not be measured, prophecy must possess a questionable value.

WASTE IN COAL MINING.

The principal loss or waste attending coal-mining operations is that represented by the quantity of coal necessarily left in the ground as pillars to support the roof. In some cases it is also necessary to leave a foot or more of coal as a part of the roof, because of the unstable character of the material overlying the coal, which itself does not make a good roof. It has also been frequently the case that, where portions of the coal bed have been of inferior quality, only the high-grade coal has been mined and the poorer material left. The coal left as pillars, or as portions of the roof, may be considered a necessary loss, but that which is left because of its inferior quality can not be considered unavoidable waste in any sense, and is frequently of higher grade than coals mined and used in other portions of the country.

Enormous quantities of coal have been lost beyond recovery from the mining of beds lying below, the caving of which, upon the withdrawal of the pillars, has so broken up the overlying strata as to render it impossible to recover the coals contained therein. This has been particularly the case in some of the coal beds of western Pennsylvania, but much improvement has been observed in this regard within later years. Notwithstanding the improvement in this respect it is probable that a large amount of coal will be wasted in the Western States, where a great number of coal beds are closely associated, and also where the intercalated strata are weak, forming poor roofs to the mines.

There are no exact figures as to the actual loss or waste sustained through coal left in the mines in conducting the mining operations, but it has been estimated that it amounts to 50 per cent of the quantity produced and marketed. In some cases, through careful mining and where the conditions are ideal for working, practically all of the contents of the coal beds are recovered. In other cases, particularly when the beds are of enormous thickness, the recovery has not exceeded 30 per cent of the contents. During the earlier days of mining in the anthracite regions of Pennsylvania it was estimated that only 40 per cent of the coal was marketed. This was partly due to uneconomical methods of mining, and partly to the large amount of culm, for which there was at that time no market and which was piled on the ground in unsightly mountains. At the time of the Anthracite Coal Waste Commission, which made its report in 1893, 40 per cent was still considered a maximum recovery. So far as underground workings are concerned, there has been no revolution in the methods employed since that time, but there has been a considerable improvement in the application of those methods, which has resulted in the recovery at the present time of a materially larger proportion of the coal in the ground than was the rule at that date. The earlier methods of mining consisted in leaving comparatively narrow pillars, and in the mining of large rooms the the result was that the pillars were not strong enough to stand the pressure and were crushed beyond recovery. It is now customary to use larger pillars between the rooms, which makes it possible to better control the roof during "robbing" operations and to eventually recover a larger proportion of the contents of the bed.

Material improvements have also been made in the methods of the preparation of coal, so that a much greater proportion of the product hoisted is now being sent to market in merchantable condition. Part of this is due to better and more systematic methods of handling, and part to the saving of small sizes which formerly went to the culm banks. The higher prices of coal and the development of methods for using these small sizes have also made it possible, through washing processes, to rework the small coal formerly thrown on the culm banks, and these are now furnishing several millions of tons of marketable coal annually.

Under present conditions, except in cases where the surface must be maintained, it is estimated that in the Wyoming region of the Pennsylvania anthracite field the recovery for market is from 60 to 64 per cent. In the Lehigh, Mahanoy, and Schuylkill regions the recovery for shipment is estimated at 56 per cent.

When the Anthracite Coal Waste Commission[a] made its report in 1893 the shipments of anthracite had amounted to 820,362,995 long tons, and the total production was estimated to have been 902,000,000 long tons. The commission estimated that for every ton produced, 1½ tons were lost, and the total exhaustion was estimated at 2,255,000,000 long tons. The estimated original contents of the field were 19,500,000,000 tons, and the estimated contents remaining at the beginning of 1893 were 17,245,000,000 tons.

The commission in its report (p. 149) says:

> It is to be doubted whether the total coal won when the field shall be abandoned will exceed 40 per cent of the total contents. An estimate on that basis would show the available marketable coal still now in the ground to be as follows:

	Tons.
Wyoming region	1,859,000,000
Lehigh region	477,500,000
Schuylkill region	4,561,500,000
In all	6,898,000,000

> The amount of coal won at the modern colliery due to improvements in mining methods, in the appliances for handling the coal, and in the utilization of the small sizes shows a decided advance over the earlier years of mining; a still further advance will undoubtedly be made in these directions, and the mining of the small beds, where a larger per cent can be won, will all tend to increase the total. Future estimates for a long time will in all probability show an advance in the total per cent won.

What the commission predicted in the foregoing paragraph has to some extent already been accomplished, from the fact that coal is now being mined from beds that were not considered a part of the available reserves when the commission made its report. In mining methods, as previously stated, there has also been a marked improvement, and the writers are of the opinion that it is safe to assume that since 1893 the 1 ton of coal lost for every ton mined is nearer the actual results than 1½ tons lost for each ton mined, and at this rate the available supply at the beginning of 1893 would have been 8,622,500,000 tons instead of 6,898,000,000 tons. The total production from 1893 to the close of 1907 has amounted to 833,187,445 long tons, which deducted from the estimated available supply of 8,622,500,000 tons would leave as the remaining available supply 7,789,312,555 long tons, it being understood that this is only one-half of the coal left

[a] The members of the commission were Eckley B. Coxe, of Drifton; Heber S. Thompson, of Pottsville; and William Griffith, of Scranton, Pa.

in the ground untouched. What may be done in the future in the way of recovery of coal which is now considered an absolutely necessary waste and lost for all time is, of course, a matter of conjecture.

In the mining of bituminous coal it is estimated that for every ton of coal produced for market one-half of a ton is lost or wasted. The part of this which is represented by the coal left in the mines for pillars, etc., may be materially reduced, but in many cases the recovery of a larger percentage of the coal in the ground can be obtained only by an increased cost of mining; and this in the face of the overdeveloped properties, keen competition, and low selling prices is incapable of accomplishment at the present day unless there be concerted legislative action by the governments of the several States.

There is another and a serious loss or waste in bituminous coal mining which is, like the culm in the anthracite fields, represented by the slack or fine coal necessarily or unnecessarily produced in mining operations. This is particularly the case when the coal is of the "dry" or noncaking variety which can not be used for coke making or which, because it does not fuse in the fire box, fails to make a satisfactory steam fuel. Many thousands of tons of this "slack" coal are thrown on the ground each year, and much of it is burned in order to prevent it from "cumbering the ground" or adding extra weight above the mine workings. A large part of this waste could be prevented by briquetting, but the process of briquetting adds about $1 per ton to the cost of the fuel, which renders competition with cheap fuel in the shape of raw coal impossible. Two of the causes which lead to the production of unnecessarily large quantities of slack are the excessive use of powder and the practice of "shooting from the solid." These reduce the percentage of large-sized or marketable coal and naturally increase the cost of that portion of the product.

Legislation prohibiting shooting from the solid, which would provide penalties for excessive use of powder, would have as one result a larger percentage of lump coal; and thus in a measure enable operators to assume the additional expense involved in the briquetting of such slack coal as is unavoidably produced.

This legislation is the province of the state governments, and it is not too much to hope that before long laws may be enacted against the accumulation of slack heaps or their useless destruction by burning, and this waste prohibited, as that of natural gas has been in some cases.

The question of the waste in the combustion or utilization of coal does not come within the scope of this paper, but as the manufacture of coke is, in reality, a preparation of the fuel for use, attention may properly be called to the enormous waste resulting from beehive oven practice (the method commonly employed in the United States).

In what is known as the beehive oven (so called because of its similarity in shape to the conventional beehive) the coal is partially consumed, or, more properly speaking, the volitile combustible contents are consumed and all of the valuable constituents of the coal, except the fixed carbon, which is left behind as coke, are wasted. These wasted constituents consist of gas, tar, and ammonia. In what are known as by-product recovery ovens, however, the process is one of distillation and the by-products of tar and ammonia and all of the gas, except that used for heating the ovens, are recovered and used.

The United States is far behind Germany and other foreign countries in adopting the economies resulting from the coking of coal in by-product ovens. In Germany at the present time little or no coke is made except in retort ovens. The first ovens of this type in the United States were built in 1893 at Syracuse, N. Y. Up to the close of 1907 the total number of this type of ovens completed was 3,892, while the number of beehive ovens in operation in that year was 94,746. The production from the retort ovens was 5,607,899 short tons of coke and that from beehive ovens 35,171,665 tons.

When the economies which may be effected by the use of the retort ovens have been so clearly demonstrated, not only by the plants which have been constructed in the United States, but more emphatically through the much more extensive development of by-product coke manufacture in Europe, the condition in the United States, as shown by the statistics for the last four years, is somewhat difficult to understand. As previously stated, the production of coke in the by-product ovens of the United States in 1907 amounted to 5,607,899 short tons. It was valued at $21,665,157. The total value of by-products obtained in the manufacture of this coke was $7,548,071, this value and the quantity being distributed as follows:

Value of by-products obtained in manufacture of coke in retort ovens in 1907.

	Quantity.	Value.
Gas....thousand cubic feet..	20,516,731	$3,130,839
Tar....gallons..	53,995,795	1,242,530
Ammonia, sulphate or reduced to equivalent in sulphate....pounds..	125,372,360	3,174,702
Total....	....	7,548,071

The gas included in the foregoing statement is the "surplus" not consumed in the coking process and is either sold or used at manufacturing establishments operated in connection with the coke-oven plant. In a few instances where the surplus gas is consumed by the producing companies the quantity is not measured, nor was any value placed upon it in the reports made to the United States Geological Survey. In such cases careful estimates have been made, based upon the average surplus gas obtained from similar coals used at ovens of the same type. The value, similarly estimated, has been placed at from 10 to 15 cents per thousand cubic feet.

The coal consumed in retort ovens in 1907 amounted to 7,460,587 short tons. The quantity of coal used in beehive ovens was 54,485,522 short tons, from all of which the possible by-products are apparently wasted. Assuming that the coal consumed in beehive ovens was of the same average quality as that charged into the retort ovens and that the prices would be not less than 80 per cent of those ruling in 1907, the value of recoverable products which were thus apparently wasted last year amounted to $44,000,000, a sum equal to nearly 80 per cent of the total value of all the coal used in beehive ovens during the year. At the prices which prevailed in 1907 the value of the by-products wasted in beehive coke ovens was a little over $55,000,000.

The value of the by-products from the retort ovens in 1907 was a little more than one-third the value of the coke produced in them. It should be remembered, however, that beehive ovens are located in the coal-mining regions and that the cost of the coal charged into them represents only a little more than that represented by the expense of mining the coal, whereas in locating by-product recovery plants provision must be made for utilizing or marketing the by-products. It is for this reason that in much the larger number of cases the recovery plants are established near the larger cities and at considerable distances from the mining regions, and the expense of transportation is added to the mining cost of the coal. Hence it is that the value of the coal charged into by-product ovens in 1907 was $15,874,430, or over $2 per ton, while that of the coal used in beehive ovens was $56,956,008, or $1.05 per ton. It must also be remembered that the original cost of installation for a by-product plant is from four to five times that of a beehive plant of equal capacity. These disadvantages are in turn partly offset by the higher percentage yield of coke in the retort ovens and a lower delivery charge on the coke produced. In the case of beehive coke, railroad transportation expense is borne by the coke, while in retort-oven practice all, or nearly all, of the freight charge is borne by the coal..

The total value of the 5,607,899 tons of by-product coke produced in 1907 was $21,665,157, an average of $3.86 per ton. The value of the 35,171,665 tons of beehive coke made in 1907 was $89,873,969, or $2.56 per ton. If we consider that the difference in the value of the by-product coke and beehive coke was due only to the difference in freight charges, then the total value of the entire product of beehive coke made in 1907 would, if made in retort ovens close to the market, have been $135,750,000. On adding to this the value of the by-products that should have been recovered, amounting to $44,000,000 at 80 per cent of the market price in 1907, the total value of the coke and by-products would have amounted to nearly $180,000,000 instead of the value of $89,873,969 for the beehive coke alone. The value of the coal charged into these ovens, however, would have been $108,879,870 instead of $56,956,008. Carrying the hypothesis further, the difference between the value of the coke and by-products if the coal had been coked in retort ovens and the value of the coke alone from the beehive ovens was, say, $90,000,000. From this should be deducted the difference between what the value of the coal would have been at retort ovens and what it was at beehive ovens, i. e., $52,000,000. The remainder ($38,000,000), less the difference in operating expenses, wear and tear, interest on capital, etc., may be considered as approximately the actual net loss in value as the result of beehive coke production compared with by-product coke practice in 1907.

One of the reasons that has been given for the apparent lack of progress in retort-oven building in the last four years is the lack of profitable markets for the by-products of coal tar, and this has contributed to the backwardness of the United States in the development of the chemical industries depending upon coal tar as a raw material, and yet this country is importing coal-tar products to the value of several million dollars annually. It is also well known that the development of the coal-briquetting industry has been retarded because of the lack of assurance of a satisfactory supply of suitable coal-tar pitch for binding material, and there is also an increasing demand for creosoting oils for the preservation of timber.

COAL SUPPLY, PRODUCTION AND EXHAUSTION, BY STATES.

Alabama.—As far as known the earliest record of the existence of coal in Alabama was made in 1834. The first statement of production is contained in the United States Census Report for 1840, in which year the production is given at 946 tons. In 1907 the production was 14,250,454 tons, and the total production from 1840 to 1907 amounted to 164,734,310 short tons, which represented an exhaustion, including the waste in mining, of 247,000,000 tons. The total coal-bearing area of the State is estimated at 14,430 square miles, and the original coal supply is estimated to have been 68,903,000,000 short tons. The exhaustion to the close of 1907 represents a little over 0.3 of 1 per cent, and the production in 1907 was a little over 0.02 of 1 per cent of the estimated original supply.

Arizona.—A small area of 30 square miles in Arizona is estimated to contain 60,000,000 tons of coal, from which there had been no production at the close of 1907.

Arkansas.—As in Alabama, the first production of coal reported in Arkansas was in the census year 1840, when 220 short tons were reported as having been mined in that State. The industry in Arkansas did not develop rapidly during the early years, as the census of 1860 shows a production of only 200 tons, and that of 1880 a total of 14,778 tons. During the last twenty years, however, there has been a marked increase in the production of coal in Arkansas, and the maximum output was reached in 1907, with a total of 2,670,438 short tons. The total production to the close of 1907 amounted to 23,756,401 short tons, equivalent to an exhaustion of approximately 36,000,000 tons. The estimated original supply of coal in Arkansas was 1,887,000,000 short tons, of which the exhaustion to date represents practically 2 per cent. The production in 1907 was equivalent to 0.15 of 1 per cent of the estimated original supply. The total area in Arkansas which contains workable coal or which may contain workable coal or lignite is estimated to be 7,584 square miles.

California.—The coal fields of California consist of scattered areas, of which, with few exceptions, comparatively little is known. The total workable area is estimated to be 500 square miles, and the original contents of the field 1,000,000,000 short tons. Mining in California had its beginning, according to the records of the state mining bureau, in 1861. The maximum production was reached in 1880, since which time the production has been irregular and has shown a declining tendency, this being due in the last few years to the increased production of oil in the State and its use for fuel purposes. The total coal production to the close of 1907 was 5,030,945 short tons, equivalent to an exhaustion of approximately 7,000,000 tons, or 0.7 per cent of the original supply.

Colorado.—Colorado is one of the Western States which is rich in coal resources. The estimated total area of the coal fields is 17,130 square miles, and the original contents of these fields are estimated to have been 371,770,000,000 short tons. Coal production began in Colorado in 1864, but it was not until 1882 that the output reached as much as 1,000,000 short tons. Since that date there has been a steady increase in production, until in 1907 it amounted to 10,790,236 short tons. The aggregate production to the close of 1907 was 112,-668,336 short tons, of which the equivalent exhaustion has been 169,-000,000 short tons, which represents a little over 0.05 of 1 per cent of the original supply. The production in 1907 was approximately 0.004 of 1 per cent of the original contents of the fields.

Georgia.—The coal fields of Georgia are limited to a small area in the northwestern part of the State, estimated to cover 167 square miles and to have contained, when mining began, 933,000,000 short tons. The census report for 1860 contains the first authentic statement of production in Georgia, and the output in that year is placed at 1,900 short tons. The production of the State in 1907 was 362,401 tons, and the total production to the close of the year was 8,123,696 short tons, representing an exhaustion of 12,000,000 tons. This would still leave in the ground a total of 921,000,000 tons, of which 650,000,000 tons would probably be considered as the available supply, and this, at the rate of production in 1907, would last approximately 1,800 years.

Idaho.—The areas in Idaho known to contain workable coal are placed at 200 square miles, while there are 1,200 square miles which are not known, but which may also contain workable coal. The estimated original contents of the coal fields of Idaho are placed at 600,000,000 tons, from which to the close of 1907 less than 25,000 tons had been mined.

Illinois.—Illinois is the second State in coal-producing importance. The area in Illinois known to contain coal is larger than that of any other State east of the Mississippi River, and if we consider only the known coal areas the coal fields of Illinois cover a wider area than those of any other coal-producing State. The coal-producing area of Illinois is estimated at 35,600 square miles, and the original contents of the fields are placed at 240,000,000,000 short tons. The earliest mention of coal in the United States is contained in the journal of Father Hennepin, a French missionary, who, as early as 1679, reported a "cole mine" on the Illinois River, near the present city of Ottawa. The earliest record of actual mining is that coal was produced in Jackson County in 1810. In 1833 the production is reported to have been 6,000 short tons. In 1907 it was 51,317,146 short tons. The total production to the close of 1907 amounted to 645,868,309 tons, representing an exhaustion of 968,000,000 short tons, from which it appears that the exhaustion to the close of 1907 has been 0.4 of 1 per cent of the total estimated supply. The quantity of coal remaining in the ground at the close of 1907 was 4,664 times the production of that year, or about 2,500 times the exhaustion represented by that production.

Indiana.—The coal fields of Indiana lie entirely in the southwestern portion of the State. They are confined within an estimated area of 6,500 square miles, and contained, when mining first began, 44,169,000,000 tons of coal. Coal mining in Indiana began sometime between 1830 and 1840, and the census of the latter year reported a production of 9,682 tons. In 1907 the production amounted to 13,985,713 short tons, and the total production to the close of that year amounted to 159,440,390 short tons. The exhaustion to the close of 1907 had been 239,000,000 short tons, or 0.54 of 1 per cent of the original supply. Upon these estimates the quantity of coal remaining in the ground in Indiana at the close of 1907 was about 3,000 times the production of that year, and 2,000 times the exhaustion represented by that production.

Iowa.—The coal fields of Iowa are estimated to contain workable coal aggregating 12,560 square miles. To this may be added 5,640 square miles of possible workable coal areas. The original contents of the fields are estimated to have been 29,160,000,000 short tons. From this there has been produced from 1840, when mining first began, to the close of 1907, a total of 141,608,792 short tons, representing an exhaustion of 212,000,000 short tons. The quantity of coal still available at the close of 1907 was 28,948,000,000 short tons. At the rate of production in 1907, in estimating half a ton lost for every ton mined, this supply would last 2,550 years.

Kansas.—The areas in Kansas known to contain workable coal are placed at 3,100 square miles, although in addition to this there are 15,780 square miles which may contain workable coal. The estimated supply, when mining first began, is placed at 7,022,000,000 short tons. From this there has been produced from 1869 (the year of earliest production) to the close of 1907 a total of 91,176,204 short tons. This represents an exhaustion, including loss in mining, of about 136,000,000 short tons, from which it would appear that about 1.9 per cent of the original supply has been exhausted. The production in 1907 was 7,322,449 short tons, equivalent to an exhaustion of 10,000,000 short tons, which would indicate, at the rate of production in 1907, that the known coal supply of Kansas would last approximately 700 years.

Kentucky.—Kentucky is the only one of the coal-producing States which has within its borders areas belonging to two of the great coal fields. The eastern counties of the State are underlain by the coal beds of the great Appalachian system, while the southern limits of the central or eastern interior field are found in the more northern counties of the western part of the State. The eastern areas contain 10,270 square miles, the contents of which, when mining began, are estimated at 67,787,000,000 short tons. The western areas contain 6,400 square miles, the original contents of which are placed at 36,240,000,000 short tons. The total estimated original supply of the State was therefore 104,027,000,000 short tons. Mining began early in the second quarter of the nineteenth century, and it is estimated that from 1829 to 1835 the production ranged from 2,000 to 6,000 tons a year. The production in 1907 was 10,753,124 short tons, and the total production to the close of the year was 122,404,574 short tons, which represents an exhaustion of 184,000,000 short tons, or 0.18 of 1 per cent of the original supply. The quantity of coal left in the ground at the close of 1907 would then be 103,844,000,000 tons, of which approximately 67,000,000,000 short tons would be considered available, or, in other words, the supply at the close of 1907 was 6,700 times the production in that year.

Maryland.—The coal fields of Maryland are confined to a limited area in Allegany and Garrett counties in the western part of the State. This area has an extent of 455 square miles and the original supply is estimated to have been 8,044,000,000 short tons. Mining began early in the nineteenth century, and shipments were made down the Potomac River in 1830. The first shipments by railroad were made in 1842, in which year 1,708 tons were shipped over the newly built Baltimore and Ohio Railroad. In 1907 the production amounted to 5,532,628 short tons, and the total production to the close of that year aggregated 147,606,548 short tons, equivalent to an exhaustion, including waste, of 221,000,000 tons, or not quite 3 per cent of the original supply. The supply still remaining at the close of 1907 was 7,823,000,000 short tons, 1,422 times the production and 948 times the exhaustion represented by the production of that year.

Michigan.—The coal fields of Michigan are the only ones within the drainage basin of the Great Lakes. They occupy an area of approximately 11,000 square miles and are estimated to have contained when mining first began a total of 12,000,000,000 short tons of coal. Although coal mining has been carried on in Michigan for about seventy years, it is only a little more than a decade since it became of any importance as an industry, the production exceeding a million tons a year for the first time in 1901. The total production to the close of 1907 was 13,842,943 short tons, which, including waste, represents an exhaustion of 21,000,000 short tons, or 0.175 of 1 per cent of the total original supply. The production of Michigan in 1907 was 2,035,858 short tons. The supply remaining at the close of that year was, according to the best estimates, 11,979,000,000 short tons, of which 7,986,000,000 tons would be considered as available. This is equivalent to 3,900 times the production of 1907.

Missouri.—The original coal supply of Missouri is estimated to have been 40,000,000,000 short tons, included within an area of 23,000 square miles. The production of the State to the close of 1907 had amounted to 97,618,106 short tons, representing an exhaustion of approximately 146,000,000 tons, or 0.36 of 1 per cent of the original supply. The production in 1907 was 3,997,936 short tons, which is equivalent to an exhaustion of approximately 6,000,000 tons. The supply remaining at the close of 1907 is about 6,500 times the exhaustion created by the production in that year.

Montana.—Montana's scattered coal fields, known to contain workable coals, aggregate 34,067 square miles, while the areas which may contain workable coal, but which are not well known, amount to 17,575 square miles. The original contents of these coal fields are estimated to have been 303,060,000,000 short tons, from which there have been mined to the close of 1907 approximately 24,740,000 tons, representing an exhaustion of 37,000,000 tons, or 0.012 of 1 per cent of the original supply. The production in 1907 of a little over 2,000,000 tons is equivalent to an exhaustion of about 3,000,000 tons, and the coal left in the ground was 100,000 times that exhausted.

New Mexico.—The coal fields of New Mexico aggregate a total area of 18,335 square miles, and the original supply is estimated to have been 163,780,000,000 short tons, from which there had been produced to the close of 1907 a total of 22,325,432 short tons, representing an exhaustion of 33,000,000 tons, or 0.02 of 1 per cent of the original supply. The production in 1907 (2,628,959 short tons) is equal to nearly 12 per cent of the entire production of the coal to the close of that year, while the coal left in the ground is nearly 65,000 times the production in 1907, and over 40,000 times the exhaustion represented by that production.

North Carolina.—Two small areas of Triassic age contain all the coal known to exist in North Carolina. The total area is about 60 square miles, and the original contents of the field are estimated at 200,000,000 short tons. These areas have never been worked to any large extent, and the total production to the close of 1907 was less than half a million tons.

North Dakota.—Although the coal fields of North Dakota are of wide extent, the coal itself is all of lignitic character and of little commercial value at the present time. The total areas supposed to contain workable lignite are placed at 35,500 square miles and the original contents have been estimated at 500,000,000,000 short tons. The production, particularly considering the large supply, has been very small, the total exhaustion to the close of 1907 having amounted to only 4,000,000 tons.

Ohio.—Compared with the supply of coal originally contained within the coal fields of Ohio, the rate of exhaustion has been greater than that of any other State in the Appalachian system, with the exception of Maryland. The estimated original supply contained within an area of 12,660 square miles was 86,028,000,000 short tons. The first record we have of the production in the State is in the year 1838, when 119,952 short tons of coal were mined. Ohio's output was at that time exceeded only by the production of Pennsylvania anthracite and bituminous coal from the Richmond basin. From 1845 to 1875 Ohio ranked second among the coal-producing States. In 1876 it was surpassed by Illinois, and since 1896, when it was surpassed by West Virginia, it has ranked fourth among the coal-producing States. In 1907 Ohio contributed 32,142,419 short tons of coal to the total product of that year. The total output of Ohio mines from 1838 to the close of 1907, a period of seventy years, has amounted to 492,769,358 short tons, representing an exhaustion of 739,000,000 tons, or something less than 0.9 of 1 per cent of the estimated original supply. The production of 1907, which was a little less than 7 per cent of the production to the close of that year, was equivalent to an exhaustion of about 48,000,000 tons. Deducting from the original supply the exhaustion at the close of 1907, there would still be available on January 1, 1908, 85,980,000,000 tons, or nearly 2,000 times the production in 1907.

Oklahoma.—All of the coal in Oklahoma is contained in that portion of the State which was formerly known as the Creek, Cherokee, and Choctaw nations of Indian Territory. The total area underlain by workable coal is estimated to be about 10,000 square miles, and the original contents are estimated to have been 79,278,000,000 tons. Mining did not begin in Indian Territory until comparatively late, the first production reported having been in 1880, when 120,947 short tons were produced. The industry has progressed rapidly, however, and the production in 1907 amounted to 3,642,658 short tons. The total production to the close of 1907 was 39,845,015 short tons, representing an exhaustion of approximately 60,000,000 tons. The quantity of coal left in the ground in Oklahoma at the close of 1907 was 13,000 times the exhaustion represented by the production in that year.

Oregon.—As far as known the earliest record of coal production in Oregon was in 1880, when the output amounted to 43,205 short tons. In 1907 Oregon's production was 70,981 short tons, and the aggregate production from 1880 to the close of 1907 was 1,790,392 tons, which represents an exhaustion of 2,700,000 tons. The total area in the State containing workable coals is estimated at 230 square miles and the original supply at 1,000,000,000 short tons.

Pennsylvania.—The supplies of anthracite coal in Pennsylvania are discussed in another portion of this paper. The bituminous areas in the western portion of the State are estimated to have an extent of 14,200 square miles and to have contained, when mining first began, 112,574,000,000 short tons. The development of the Pennsylvania bituminous coal fields did not begin until about twenty years after anthracite mining was established as an industry, the first production having been reported in the census year 1840, when 464,826 short tons were mined. Up to 1897 the production of anthracite coal in Pennsylvania exceeded that of bituminous, but in 1898 the bituminous production took the lead and has continued to lead since that date. In 1907 the production of bituminous coal exceeded that of anthracite by nearly 80 per cent, and as indicative of the extent to which the bituminous coal-mining industry of Pennsylvania has grown it may be stated that the production in 1907 was nearly three times that of 1897, only ten years before. The total production of bituminous coal in Pennsylvania to the close of 1907 was 1,846,069,253 short tons, which was equivalent to an exhaustion of 2,760,000,000 tons, or 2.5 per cent of the original supply. The exhaustion represented by the production in 1907 was 225,000,000 tons. The supply remaining at the close of 1907 was 109,804,000,000 tons, or 492 times the exhaustion represented by the production of that year.

South Dakota.—The northwest corner of South Dakota contains the southern extension of the North Dakota lignite beds, and it is estimated that about 6,000 square miles of this territory may contain workable lignites. The contents are estimated at 10,000,000,000 short tons, and these are practically untouched.

Tennessee.—The coal fields of Tennessee are contained in a narrow strip in the eastern counties of the State, where the Appalachian province crosses the State in a northeast-southwest direction. Mining began sometime between 1830 and 1840, and the census for the latter year reported a production of 558 tons. Coal mining did not, however, develop into an important industry in Tennessee until after the close of the civil war, and it was not until 1883 that the production reached as much as 1,000,000 tons annually. Since that time it has increased with notable regularity, until in 1907 the production amounted to 6,810,243 short tons. The total area of bituminous coal in the State is estimated at 4,400 square miles, and the total original supply at 25,665,000,000 tons. The total production to the close of 1907 amounted to 84,304,601 short tons, representing an exhaustion of approximately 126,000,000 tons, or about 0.5 of 1 per cent of the original supply. The exhaustion represented by the production in 1907 was approximately 10,200,000 tons, and the supply left in the ground at the close of the year was equal to 2,500 times this exhaustion.

Texas.—The known bituminous coal fields of Texas are estimated to contain 8,200 square miles, and the exploited lignite fields 2,000 square miles. In addition to this there are 5,300 square miles which may contain workable bituminous coal and 53,000 square miles which may contain workable lignite. The estimated contents of the bituminous coal fields when mining first began in Texas were 8,000,000,000 short tons, and of the lignite fields 23,000,000,000 short tons. The exploitation of both the lignite and the bituminous areas is of comparatively recent date, no production having been reported from Texas prior to 1884, and it was not until 1901 that the output reached as much as 1,000,000 tons. The production to the close of 1907 was 14,444,948 short tons, representing an exhaustion of 22,000,000 tons, or 0.07 of 1 per cent of the original supply.

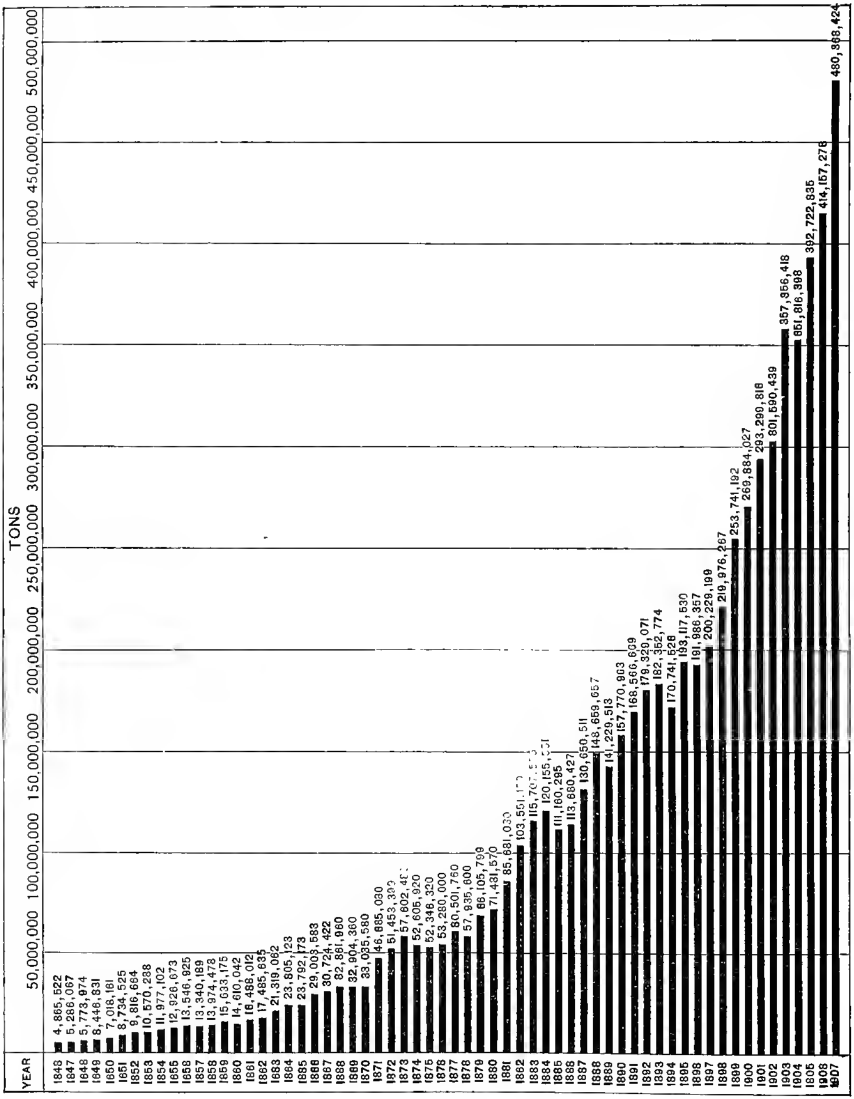
Utah.—Utah's coal fields are contained in scattered areas aggregating 15,130 square miles. The quality of the coals ranges from subbituminous to anthracite. The estimated original supply was 196,458,000,000 short tons, from which the exhaustion, including waste, at the close of 1907, was 28,000,000 short tons, indicating that there were still remaining in the ground 196,430,000,000 tons, or a little more than 100,000 times the production of 1907.

Virginia.—The Richmond basin in Virginia, where coal mining in the United States was first carried on, contains 150 square miles. Another small area in Montgomery County contains 200 square miles of coal-productive territory, but the principal regions are in the southwestern corner of the State, which is crossed by the Appalachian system. The portion of the Appalachian coal field in Virginia is estimated to be 1,550 square miles. The original supply has been placed at 22,500,000,000 short tons. From this there had been produced at the close of 1907 a total of 57,229,152 short tons, representing an exhaustion of 86,000,000 tons. The production in 1907 was 4,710,895 short tons, equivalent to an exhaustion of a little over 7,000,000 tons, so that the coal left in the ground in Virginia at the close of 1907 was 2,000 times the exhaustion represented by the production of that year.

Washington.—Washington's coal supply is contained within a number of areas that are scattered over the State and aggregate approximately 1,100 square miles. The estimated original supply was 20,000,000,000 short tons, and while mining began there as early as 1860, the total production to the close of 1907 was only 43,108,697 short tons, of which nearly 50 per cent was produced within the last seven years. The exhaustion represented by the production to the close of 1907 was 64,000,000 short tons, which is equivalent to about one-third of 1 per cent of the original supply. The quantity of coal still in the ground at the close of 1907 was estimated to be 19,936,000,000 short tons, equivalent to 5,400 times the production of 1907 and 3,600 times the exhaustion made by that output.

West Virginia.—The total area containing workable coal in Virginia is 17,000 square miles, and the original supply when mining first began was 231,039,000,000 tons. West Virginia was not admitted as a State until 1863, in which year the production amounted to 444,648 short tons. The quantity of coal mined prior to that time, in the portion of Virginia which afterwards became West Virginia, was not sufficient to materially affect the total output. For a number of years West Virginia has been third among the coal-producing States, and in 1907 the production amounted to a little over 48,000,000 tons. The aggregate production to the close of 1907 was 434,198,539 short tons, equivalent to an exhaustion of 650,000,000 tons. At the beginning of 1908 there still remained available in the coal fields of West Virginia 230,389,000,000 short tons, nearly 4,800 times the production in 1907, or 3,200 times the exhaustion represented by the 1907 output.

Wyoming.—The estimated original coal supply of Wyoming is larger than that credited to any other coal-producing State, with the exception of North Dakota. In the latter State, however, the entire supply is lignite, while in Wyoming the coals are of subbituminous or of bituminous character. The total area which may contain



PRODUCTION OF COAL IN THE UNITED STATES FROM 1846 TO 1907

workable coals has been estimated at 50,793 square miles, and the contents of this field, when mining first began, at 424,085,000,000 short tons. In comparison the aggregate production at the close of 1907, which was 77,818,765 short tons, appears insignificant. The total exhaustion of the beds to the close of 1907 amounted to 116,000,000 short tons, or 0.027 of 1 per cent of the total estimated supply.

ESTIMATES OF FUTURE COAL PRODUCTION.

By Henry Gannett,
United States Geological Survey.

The Geological Survey estimates the amount of coal remaining in the ground to be 3,147,043,000,000 tons, of which about two-thirds is easily obtainable, the other third being of indifferent or poor quality and difficult of mining.

In nearly a century of mining about one-third of 1 per cent of the supply has been taken out of the ground. The production during the year 1907, which was more than 480,000,000 tons, was much larger than in any previous year.

The Geological Survey also estimates that in mining practice about 1 ton of coal is lost for every 2 tons won, either by leaving it in the ground or in breaking and transporting.

In order to reach even an approximate idea of the length of time that this coal supply will last, it is necessary in the first place to estimate the probable annual production in the future. That it will increase beyond the present maximum goes without saying, but at what rates and for how long a period will the increase continue are questions whose solution can only be guessed. Unfortunately we have very few data upon which to build. The rate of yearly increase of production is very irregular, so irregular that no conclusions can be drawn from it. It is impossible to construct from it a smooth curve which might be projected into the future. Even if ten-year averages be taken, and the rate of progress be thus obtained per decade, the result is very unsatisfactory, for the reason that one of the decades may consist mainly of a period of prosperity while the preceding and succeeding decades may contain periods of business depression. It is necessary, therefore, in order to obtain rates of increase which are fairly comparable with one another that we take the rate of production for periods sufficiently long to include a period of prosperity with one of business depression, i. e., twenty years. This has been done with the following results, expressed in terms of millions of tons, each the production of twenty years, with percentages of increase:

Production of coal and rate of increase, by twenty-year periods, 1828 to 1907.

Years.	Production.	Per cent of increase.
	Millions of tons.	
1828–1847	37.3	......
1848–1867	306.0	720
1868–1887	1,451.0	374
1888–1907	5,068.0	249

We have here three rates of increase and they show a very rapid decrease. It would, of course, be folly to assume that the latest rate of increase, 249 per cent, is to continue indefinitely or even at all. There is every indication that the next twenty years will show a great diminution; indeed, at the present rate of increase of production, all the coal would be exhausted before the end of the present century.

The normal curve formed by rates of increase is a hyperbola—that is, if population or production, etc., is not interfered with by extraneous influences, it tends to increase in a constantly diminishing ratio, but never ceases to increase, and the successive rates of increase when plotted to scale form a hyperbolic curve. The equation of this curve, referred to its asymptotes, is $(x - a)\ (y - b) = c$. We have three points on this curve, i. e.:

$$x=1 \qquad y=720$$
$$x=2 \qquad y=374$$
$$x=3 \qquad y=249$$

x being periods of time, in this case twenty-year intervals, and y being the corresponding per cents of increase.

Using these values in the above equation, we obtain for the constants:

$$a= 13$$
$$b= 17$$
$$c=833$$

Substituting these values of the constants in the equation, and giving x successively values of 4, 5, 6, etc., the following values for y, the per cents of increase, are obtained, as shown below, with the resulting amount of coal production in each successive twenty-year period:

Estimated production of coal and rate of increase, by twenty-year periods, 1908–2067.

Years.	Per cent of increase.	Production.
		Millions of tons.
1908–1927	185	21,375
1928–1947	145	52,369
1948–1967	119	114,688
1968–1987	100	229,376
1988–2007	85	424,346
2008–2027	74	738,362
2028–2047	65	1,218,297
2048–2067	58	1,924,909

The production for the double decade 2048–2067 is estimated at the enormous rate of 274 tons (including waste) for every man, woman, and child in the country, or, excluding waste, 183 tons per capita.

As is seen above, the easily accessible coal may be exhausted about the year 2040, and all coal about the middle of that century; i. e., ten years later.

It must not be supposed, however, that this programme will be carried out. In the first place, the data upon which this curve has been constructed are very few, and the curve is correspondingly weak. They are, however, all that we possess and the foregoing is probably the best way to use them.

In the future, powerful extraneous influences will come to bear on coal production, and all, as far as can be foreseen, except possible exports, are in favor of lengthening the life of the supply.

As soon as the end appears in sight the price will rise and production diminish, and that progressively. This interference with the law of decreasing increase, produced by growing scarcity, will of course prolong the life of our coal reserves, but at the same time will greatly hamper our industries dependent on this fuel.

Again, the development of water power will prove another disturbing factor which will prolong the life of our coal supply. To a great extent, city heating and lighting and power for manufacturing, and transportation will in the near future be furnished by water power. It is estimated that in round numbers 30,000,000 horsepower are going to waste in our streams to-day, most of which can and will be utilized, replacing coal. If all the latent water power in the country were harnessed within the next twenty years, it would probably prolong the life of the coal supply by about eighty years.

Furthermore, the economies to be introduced in mining and handling coal will result in saving a large part of the present waste. If the production and transportation were relieved of all waste within the next twenty years, the coal supply would last twenty years longer.

THE PETROLEUM RESOURCES OF THE UNITED STATES.

By David T. Day,
United States Geological Survey.

EXTENT OF THE PETROLEUM FIELDS.

This report deals with the petroleum fields of the United States as known at present; that is, it is limited to the petroleum pools actually developed, or what is known as "proved territory."

LOCATION.

The areas where petroleum is known to occur at present are shown on the accompanying map of the United States.

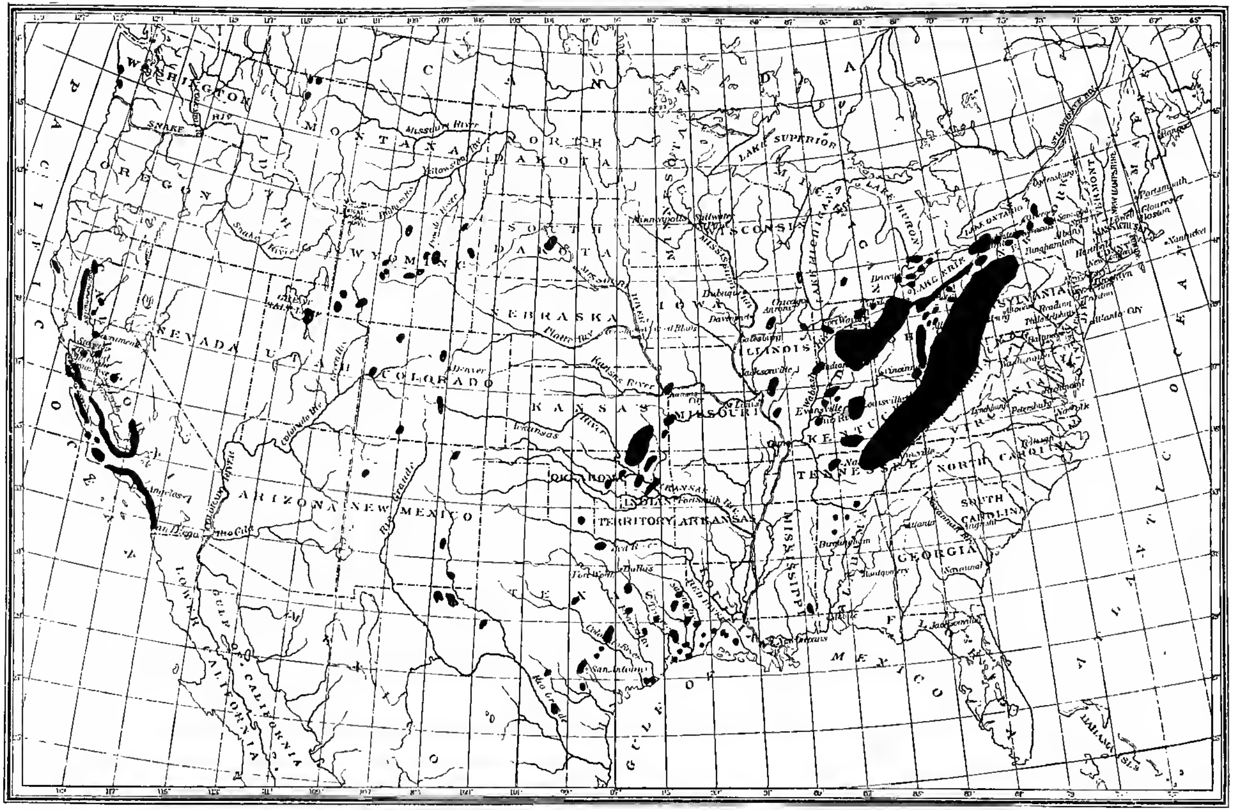
Appalachian.—Petroleum is unknown and improbable east of the Allegheny Mountains. Parallel with their western flank the Appalachian belt extends from western New York to Tennessee. It crosses western Pennsylvania, and there petroleum was first found in large quantity. The supply in Pennsylvania is rapidly becoming exhausted. It has declined to one-third of its highest rate of production. This high-production mark was only seventeen years ago. The Appalachian field continues across West Virginia and includes the eastern edge of Ohio. Farther south moderate supplies have long been known, and they are still being developed in Kentucky and Tennessee.

"Petroleum" in this report means crude petroleum, as it comes from the earth; that is, before it has been refined. The word "oil" refers to products obtained from petroleum.

The petroleum of this field (known generally as Pennsylvania petroleum) differs essentially from that of the other fields in the United States. It is notably different from any other petroleum thus far found in the world. It is most easily converted into lamp oil, and yields the greatest percentage of this product. The lamp oil is the finest yet produced—in fact, much better than any other except the products from western Ohio and Indiana, and the petroleum from this latter field costs more to refine.

Farther south, in Kentucky and Tennessee, the product is progressively poorer, but is much better than Russian or any other of the foreign products with which it comes in competition.

Lima-Indiana.—The second great field in historical development covers a considerable portion of northwestern Ohio and eastern Indiana, and small isolated pools of petroleum of the same general character are found elsewhere in Indiana. This petroleum is more



PETROLEUM AND NATURAL GAS FIELDS.

uniform than the Pennsylvania varieties. It contains, quite uniformly, less gasoline and less lamp oils, and the presence of organic sulphur compounds results in an average of one-half of 1 per cent of sulphur, which can be removed only by ingenious and comparatively costly refining processes.

Illinois.—In Illinois, near the eastern edge, a strip of territory some 30 miles long and of irregular width, averaging about 6 miles, is yielding a comparatively enormous quantity of petroleum. It is freer from sulphur than the Lima-Indiana variety, and occasionally contains sufficient asphalt to ally it to the petroleum from the next field to the west, the Mid-Continent field.

Mid-Continent.—This comprises the pools in Kansas and Oklahoma, and must eventually include, for statistical purposes, the pools in northwestern Louisiana and northern Texas. The yield from this field within the last two years has been so large as to greatly disturb the industry, on account of the difficulty of providing sufficient refining and transportation facilities. This petroleum differs from Pennsylvania petroleum in frequently containing small amounts of asphalt, and also in containing hydrocarbons less stable in their action toward the chemicals used in refining them. Nevertheless, it has proved possible to obtain good yields of perfectly satisfactory products covering the entire range from gasoline to paraffin wax. Some of the petroleum of this field contains sufficient water and other foreign materials to complicate the matter of giving it a just valuation, and also to add to the difficulty of the refining processes.

In the Mid-Continent field the Glenn pool, located a few miles south of Tulsa, Okla., is a good illustration of the uncertainties of petroleum production. A well drilled in 1905 happened to be located a few feet within the limits of this pool. Had it been located slightly farther to the east the field would not then have been discovered, but the very considerable flow from this well caused more than usual excitement, and nearly all of the wells drilled to the west proved good producers. The wells produced 1,000,000 barrels from 1,000 acres of ground within the year 1906. Well drilling was so rapid, in fact, that the pool reached its maximum production thirteen months after the discovery of the first well, and from that time the production declined almost as rapidly as it had increased, until the decline was arrested by cleaning out the wells, and afterward, also, shooting them with nitroglycerine. The transportation companies could not keep up with such rapid development, and perhaps 1,000,000 barrels of petroleum was wasted on the ground within two years.

Gulf.—For many years the escape of petroleum and natural gas to the surface has been noted at many points in Texas and in southern Louisiana. This led to the drilling, in 1901, of a well at Spindle Top, near Beaumont, Tex., from which probably more than 500,000 barrels of petroleum flowed before the well could be checked. The field was soon extended to Jennings and Welsh, and eventually to Anse la Butte, in Louisiana. Other wells were rapidly drilled, resulting in a large addition to the petroleum product of the United States. This petroleum contains a large percentage of asphaltum and relatively small amounts of gasoline and lamp oils, and therefore offers little temptation to the refiner. It is also handicapped by the presence of sulphur in many forms. For some years it was disposed of principally to the railroads and burned as fuel on locomotives, and thus caused considerable industrial development in Texas, because it was necessary to sell the petroleum at prices as low as 10 cents per barrel in order to find a market for the product. After persistent endeavor it has become possible to refine this petroleum successfully, and some of the products have peculiar value. The lubricating oils find considerable favor and the gasoline has special value as a solvent.

California.—Petroleum, principally asphaltic and similar to the Texas petroleum, except that it is sometimes free from sulphur, is found in many areas in California, between Los Angeles and San Francisco, the principal fields being Los Angeles City, Puente Hills, Kern River, Sunset, McKittrick, Santa Maria, Coalinga, and Fullerton. The lack of an adequate supply of fuel in California has led to very great development of the petroleum industry for this purpose, as shown in the production tables below, and investigations have shown that the quantity of petroleum existing in California is greater than in any other known field in the United States.

Smaller fields.—The great fields described above are those which control the industry. West of the Mid-Continent field and east of the California field are several smaller ones (as thus far developed) in Colorado and Wyoming, with promises of fields in New Mexico, Utah, Idaho, Montana, Oregon, and Washington. In Alaska at least two petroleum pools have been discovered which may possibly be capable of considerable output when the market conditions become favorable.

There are many regions in the United States where there is no geological improbabality of finding petroleum. Such geological improbability exists where the rocks are greatly disturbed and broken up to such a depth as to prevent probable drilling to the undisturbed sedimentary rocks which could furnish good storage for petroleum.

AREAS.

In each petroleum field it has become necessary for the pipe-line companies and for the producers themselves to locate on detailed maps every well as it is drilled, distinguishing the productive from dry wells, in order that the limitations of each field may be promptly determined. From these maps, principally, with the aid of many independent data collected by himself, Dr. F. H. Oliphant has compiled a map of the petroleum fields in the United States, which is appended to this report. From measurements of the areas on this map, together with revisions from the map recently published by Dr. I. C. White, state geologist of West Virginia, and with the aid of Dr. H. Foster Bain, director of the Geological Survey of Illinois; Ralph Arnold, in charge of the petroleum investigations in California for the United States Geological Survey; A. C. Veatch, for Wyoming; Dr. J. A. Bownocker, state geologist of Ohio; and with additional data from Doctor Oliphant, the following table has been compiled, giving in square miles the area of petroleum territory in each State. The figures here given are merely general approximations, which lack very much in uniformity. In some States the area shows simply actual "proved territory." In others, as in Alabama, it indicates the region in which the future production of petroleum is probable. In many others considerable territory is included between individual pools which in all probability will prove to be barren, and while the extensions of "proved territory" will, to a certain extent, offset that which proves eventually to be barren, the table is, at best, a rough approximation. It takes no account whatever of the fact that other fields now altogether unknown will be developed in the future.

State.	Square miles.	State.	Square miles.	State.	Square miles.
Alaska	100	Louisiana	60	Pennsylvania	2,000
Alabama	50	Michigan	80	Tennessee	80
California	850	Missouri	30	Texas	400
Colorado	200	New Mexico	80	Utah	40
Idaho	10	New York	300	West Virginia	570
Illinois	200	Ohio:		Wyoming	750
Indiana	1,000	Eastern	115		
Kansas	200	Western	535	Total	8,450
Kentucky	400	Oklahoma	400		

THICKNESS.

The thickness of the "pay sands" in these fields varies within wide limits. In West Virginia Doctor White considers 5 feet of "pay sand" to be a safe estimate in good producing territory. This is sufficiently liberal for Pennsylvania also. In other fields much thicker "pay sands" are recognized. In Illinois the "pay" streaks in the petroleum sands vary from 2 feet to over 30 feet in thickness, and at Spindle Top, in Texas, an average thickness of over 75 feet has been calculated. In California, particularly in the Kern River field, the "pay sands" reach a thickness of over 100 feet.

POROSITY.

The rocks composing the "pay" streaks in the petroleum-bearing formations of the United States vary from sandstones and dolomites, with the compactness of ordinary building stone, to unconsolidated sands and coarse gravel, and, in exceptional cases, honeycombed limestones, in which actual cavities of considerable size have to be reckoned with. It has been customary to consider 10 per cent as near the average porosity of the "pay sands," with a latitude of variation from practically nothing in damp shales to over 30 per cent in the most porous strata.

The principal effect of these variations in porosity is rather upon the rate at which the petroleum can be obtained from the pool than upon the total amount obtainable.

PROBABLE SUPPLY OF PETROLEUM.

CAPACITY OF SANDS.

Assuming 10 per cent as the average porosity of "pay sands," 1 cubic foot of "pay sand" would yield approximately 1 gallon of petroleum, or 5,000 barrels per acre of "pay sands" with an average thickness of 5 feet.

ESTIMATES OF YIELD.

The thickness most frequently reported for the "pay sands" of various fields is normally much in excess of 5 feet. In Pennsylvania, the reported thickness of petroleum-bearing strata will average more than this, and frequently more than one stratum has been noted in the same well, and yet, as will be shown in the tables of production below, the average yield per acre in Pennsylvania has been less than 800 barrels, and at the present rate of decline it is not probable that more than 800 barrels per acre will be obtained on the average in New York and Pennsylvania. It is fair to assume that 1,000 barrels per acre is a sufficient allowance for New York, Pennsylvania, West Virginia, Kentucky, Tennessee, Ohio, and Indiana. In Illinois, where the yields have been unusually great on account of "pay" streaks approximating 25 feet on the average, Doctor Bain estimates 8,000 barrels per acre as the result of conferences with the producers. This is taking into consideration the fact that in the northern portions of the field the yield is frequently not greater than 2,500 barrels per acre. In the Texas field the supply is better calculated by consideration of the amount already yielded and the rate of decline, from which it is estimated that the Texas fields will surely yield 200,000,000 barrels, and Louisiana 50,000,000 barrels. In Oklahoma the remaining productive capacity is estimated by Mr. W. J. Reed, of the United States Geological Survey, at a minimum of 282,875,000 barrels. In the remaining fields, outside of California, 1,000 barrels per acre is believed to be a sufficient allowance for the known fields.

In California very careful measurements by Mr. Arnold have resulted in an estimate of 8,500,000,000 barrels of petroleum stored in the rocks of that State, of which perhaps 5,000,000,000 barrels may be expected to be produced. Recognizing that the amount of oil obtainable from these known fields is a matter largely of conjecture, it can only be based as above, upon what the fields have already yielded, and upon the thickness and relative porosity of the sands, but estimates of different authorities must vary between wide limits, and this should be borne in mind in considering the following table.

Estimated minimum and maximum total yield of the petroleum fields of the United States.

	Minimum.	Maximum.
Appalachian field	2,000,000,000	5,000,000,000
Lima-Indiana field	1,000,000,000	3,000,000,000
Illinois field	350,000,000	1,000,000,000
Mid-Continent field	400,000,000	1,000,000,000
Gulf field	250,000,000	1,000,000,000
California field	5,000,000,000	8,500,000,000
Minor fields	1,000,000,000	5,000,000,000
Total	10,000,000,000	24,500,000,000

PRODUCTION OF PETROLEUM.

BEGINNING OF THE INDUSTRY.

Production of petroleum in the United States has been considered statistically only since 1859. The production to that date incidental to the salt industry, and the occasional use of petroleum from springs for medicinal purposes, had no bearing on the industry which was to follow, except in one way. Samuel Kier, of Pittsburg, had salt wells at Tarentum, from which he accumulated so much petroleum (more than 50 barrels) that he applied himself to the problem of developing a definite trade for it, and succeeded by means of introducing a lamp with a chimney. He also partly refined this petroleum. A. C. Ferris, also of Pittsburg, applying himself in the same direction, began the distribution of this oil to other cities, and the efforts of these two merchants created and maintained a demand which caused Colonel Drake to drill a well for petroleum at Titusville in 1859. In the course of the half century since the drilling of the Drake well 1,806,608,463 barrels of petroleum, or 240,919,676 tons, have been produced, worth $1,654,877,685. Details of this production are shown in the following table:

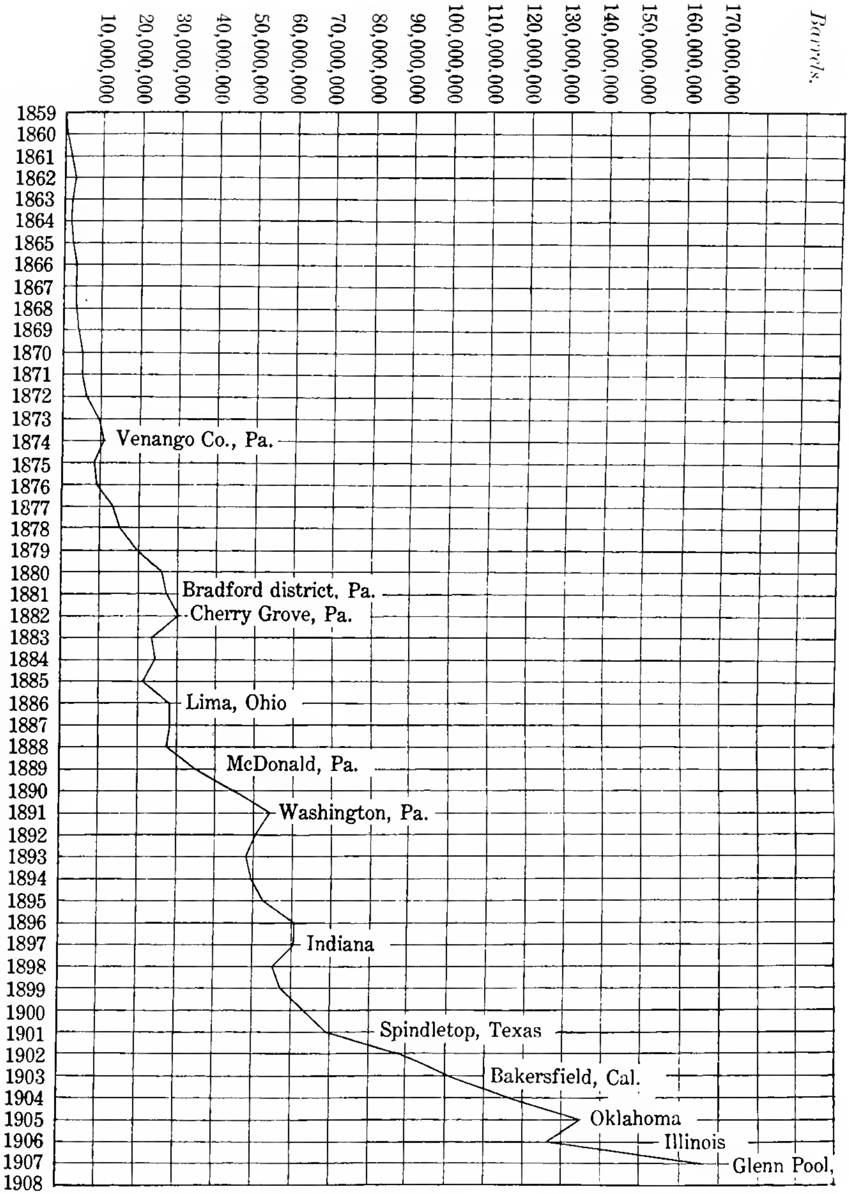
Production of crude petroleum in the United States, 1859–1907, by years and by States, in barrels of 42 gallons.

Year.	Pennsylvania and New York.	Ohio.	West Virginia.	California.	Kentucky and Tennessee.	Colorado.	Indiana.	Illinois.
1859	2,000	....	....	....	....	....	....	....
1860	500,000	....	....	....	....	....	....	....
1861	2,113,609	....	....	....	....	....	....	....
1862	3,056,690	....	....	....	....	....	....	....
1863	2,611,809	....	....	....	....	....	....	....
1864	2,116,109	....	....	....	....	....	....	....
1865	2,497,700	....	....	....	....	....	....	....
1866	3,597,700	....	....	....	....	....	....	....
1867	3,347,300	....	....	....	....	....	....	....
1868	3,646,117	....	....	....	....	....	....	....
1869	4,215,000	....	....	....	....	....	....	....
1870	5,260,745	....	....	....	....	....	....	....
1871	5,205,234	....	....	....	....	....	....	....
1872	6,293,194	....	....	....	....	....	....	....
1873	9,893,786	....	....	....	....	....	....	....
1874	10,926,945	....	....	....	....	....	....	....
1875	8,787,514	....	....	....	....	....	....	....
1876	8,968,906	31,763	120,000	12,000	....	....	....	....
1877	13,135,475	29,888	172,000	13,000	....	....	....	....
1878	15,163,462	38,179	180,000	15,227	....	....	....	....
1879	19,685,176	29,112	180,000	19,858	....	....	....	....
1880	26,027,631	38,940	179,000	40,552	....	....	....	....
1881	27,376,509	33,867	151,000	99,862	....	....	....	....
1882	30,053,500	39,761	128,000	128,636	....	....	....	....
1883	23,128,389	47,632	126,000	142,857	4,755	....	....	....
1884	23,772,209	90,081	90,000	262,000	4,148	....	....	....
1885	20,776,041	661,580	91,000	325,000	5,164	....	....	....
1886	25,798,000	1,782,970	102,000	377,145	4,726	....	....	....
1887	22,356,193	5,022,632	145,000	678,572	4,791	76,295	....	....
1888	16,488,668	10,010,868	119,448	690,333	5,096	297,612	....	....
1889	21,487,435	12,471,466	544,113	303,220	5,400	316,476	33,375	1,460
1890	28,458,208	16,124,656	492,578	307,360	6,000	368,842	63,496	900
1891	33,009,236	17,740,301	2,406,218	323,600	9,000	665,482	136,634	675
1892	28,422,377	16,362,921	3,810,086	385,049	6,500	824,000	698,068	521
1893	20,314,513	16,249,769	8,445,412	470,179	3,000	594,390	2,335,293	400
1894	19,019,990	16,792,154	8,577,624	705,969	1,500	515,746	3,688,666	300
1895	19,144,390	19,545,233	8,120,125	1,208,482	1,500	438,232	4,386,132	200
1896	20,584,421	23,941,169	10,019,770	1,252,777	1,680	361,450	4,680,732	250
1897	19,262,066	21,560,515	13,090,045	1,903,411	322	384,934	4,122,356	500
1898	15,948,464	18,738,708	13,615,101	2,257,207	5,568	444,383	3,730,907	360
1899	14,374,512	21,142,108	13,910,630	2,642,095	18,280	390,278	3,848,182	360
1900	14,559,127	22,362,730	16,195,675	4,324,484	62,259	317,385	4,874,392	200
1901	13,831,996	21,648,083	14,177,126	8,786,330	137,259	460,520	5,757,086	250
1902	13,183,610	21,014,231	13,513,345	13,984,268	185,331	396,901	7,480,896	200
1903	12,518,134	20,480,286	12,899,395	24,382,472	554,286	483,925	9,186,411	....
1904	12,239,026	18,876,631	12,644,686	29,649,434	998,284	501,763	11,339,124	....
1905	11,554,777	16,346,660	11,578,110	33,427,473	1,217,337	376,238	10,964,247	181,084
1906	11,500,410	14,787,763	10,120,935	33,098,598	1,213,548	327,582	7,673,477	4,397,050
1907	11,211,606	12,207,448	9,095,296	39,748,375	820,844	331,851	5,128,037	24,281,973
Total	687,425,409	366,250,105	185,039,718	201,965,825	5,276,578	8,874,285	90,127,511	28,866,683

Production of crude petroleum in the United States, 1859–1907, by years and by States, in barrels of 42 gallons—Continued.

Year.	Kansas.	Texas.	Missouri.	Oklahoma.	Wyoming.	Louisiana.	United States.	Total value.
1859	...	...	...	...	...	...	2,000	$32,000
1860	...	...	...	...	...	...	500,000	4,800,000
1861	...	...	...	...	...	...	2,113,609	1,035,668
1862	...	...	...	...	...	...	3,056,690	3,209,525
1863	...	...	...	...	...	...	2,611,309	8,225,663
1864	...	...	...	...	...	...	2,116,109	20,896,576
1865	...	...	...	...	...	...	2,497,700	16,459,853
1866	...	...	...	...	...	...	3,597,700	13,455,398
1867	...	...	...	...	...	...	3,347,300	8,066,093
1868	...	...	...	...	...	...	3,646,117	13,217,174
1869	...	...	...	...	...	...	4,215,000	23,730,450
1870	...	...	...	...	...	...	5,260,745	20,503,754
1871	...	...	...	...	...	...	5,205,234	22,591,180
1872	...	...	...	...	...	...	6,293,194	21,440,503
1873	...	...	...	...	...	...	9,893,786	18,100,464
1874	...	...	...	...	...	...	10,926,945	12,647,527
1875	...	...	...	...	...	...	8,787,514	7,368,133
1876	...	...	...	...	...	...	9,132,669	22,982,822
1877	...	...	...	...	...	...	13,350,363	31,788,566
1878	...	...	...	...	...	...	15,396,868	18,044,520
1879	...	...	...	...	...	...	19,914,146	17,210,708
1880	...	...	...	...	...	...	26,286,123	24,600,638
1881	...	...	...	...	...	...	27,661,238	23,512,051
1882	...	...	...	...	...	...	30,349,897	23,631,165
1883	...	...	...	...	...	...	23,449,633	25,740,252
1884	...	...	...	...	...	...	24,218,438	20,476,924
1885	...	...	...	...	...	...	21,858,785	19,193,694
1886	...	...	...	...	...	...	28,064,841	20,028,457
1887	...	...	...	...	...	...	28,283,483	18,856,606
1888	...	...	...	...	...	...	27,612,025	17,950,353
1889	500	48	20	...	...	...	35,163,513	26,963,340
1890	1,200	54	278	...	...	...	45,823,572	35,365,105
1891	1,400	54	25	30	...	...	54,292,655	30,526,553
1892	5,000	45	10	80	...	...	50,514,657	25,906,463
1893	18,000	50	50	10	...	...	48,431,066	28,932,326
1894	40,000	60	8	130	2,369	...	49,344,516	35,522,095
1895	44,430	50	10	37	3,455	...	52,892,276	57,691,279
1896	113,571	1,450	43	170	2,878	...	60,960,361	58,518,709
1897	81,098	65,975	19	625	3,650	...	60,475,516	40,929,611
1898	71,980	546,070	10	...	5,475	...	55,364,233	44,193,359
1899	69,700	669,013	132	...	5,560	...	57,070,850	64,603,904
1900	74,714	836,039	[a] 1,602	6,472	5,450	...	63,620,529	75,752,691
1901	179,151	4,393,658	[b] 2,335	10,000	5,400	...	69,389,194	66,417,335
1902	331,749	18,083,658	[a] 757	37,100	6,253	548,617	88,766,916	71,178,910
1903	932,214	17,955,572	[a] 3,000	138,911	8,960	917,771	100,461,337	94,694,050
1904	4,250,779	22,241,413	[a] 2,572	1,366,748	11,542	2,958,958	117,080,960	101,175,455
1905	[c] 12,013,495	28,136,189	[a] 3,100	([d])	8,454	8,910,416	134,717,580	84,157,399
1906	[c] 21,718,648	12,567,897	[a] 3,500	([d])	[e] 7,000	9,077,528	126,493,936	92,444,735
1907	[c] 45,933,649	12,322,696	[a] 4,000	([d])	9,339	5,000,221	166,095,335	120,106,749
Total	85,881,278	117,819,991	21,471	1,560,313	85,785	27,413,511	1,806,608,463	1,654,877,685

[a] Includes the production of Michigan.
[b] Includes production of Michigan and small production in Oklahoma.
[c] Includes production of Oklahoma.
[d] Included with Kansas.
[e] Estimated.



ANNUAL PRODUCTION OF PETROLEUM 1859 TO 1907.

New petroleum fields have been found and developed so rapidly as to more than offset the decrease of production in the older fields. Therefore, the rate of total production has shown a rapid increase from 500,000 barrels in 1860 to over 166,000,000 barrels in 1907. The rate of production is illustrated by the accompanying curve, on which are noted the sudden impulses resulting from the discovery of new fields. Grouped by the principal fields, the production of petroleum in the United States has been as follows:

Production of petroleum fields in each year from 1859 to 1907.

[Barrels of 42 gallons.]

Year.	Appalachian.	California.	Lima-Indiana.	Colorado-Wyoming.	Mid-Continent.	Gulf.	Illinois.	Total.
1859	2,000							2,000
1860	500,000							500,000
1861	2,113,609							2,113,609
1862	3,056,690							3,056,690
1863	2,611,309							2,611,309
1864	2,116,109							2,116,109
1865	2,497,700							2,497,700
1866	3,597,700							3,597,700
1867	3,347,300							3,347,300
1868	3,646,117							3,646,117
1869	4,215,000							4,215,000
1870	5,260,745							5,260,745
1871	5,205,234							5,205,234
1872	6,293,194							6,293,194
1873	9,893,786							9,893,786
1874	10,926,945							10,926,945
1875	8,787,514	3,000						8,790,514
1876	9,120,669	12,000						9,132,669
1877	13,337,363	13,000						13,350,363
1878	15,381,641	15,227						15,396,868
1879	19,894,288	13,543						19,907,831
1880	26,245,571	40,552						26,286,123
1881	27,561,376	99,862						27,661,238
1882	30,221,261	128,636						30,349,897
1883	23,306,776	142,857						23,449,633
1884	23,956,438	262,000						24,218,438
1885	21,533,785	325,000	36,178					21,894,963
1886	26,549,827	377,145	1,064,025					27,990,997
1887	22,878,241	678,572	4,650,375	76,295				28,283,483
1888	16,941,397	690,333	9,682,683	297,612				27,612,025
1889	22,355,225	303,220	12,186,564	316,476	500	48	1,460	35,163,493

Production of petroleum fields in each year from 1859 to 1907—Continued.

Year.	Appalachian.	California.	Lima-Indiana.	Colorado-Wyoming.	Mid-Continent.	Gulf.	Illinois.	Total.
1890	30,073,307	307,360	15,078,378	368,842	1,200	54	900	45,830,041
1891	35,848,777	323,600	17,452,612	665,480	1,430	54	675	54,292,628
1892	33,432,377	385,049	15,867,675	824,000	5,080	45	521	50,514,747
1893	31,365,890	470,179	15,982,097	594,390	18,010	50	400	48,431,016
1894	30,783,424	705,969	17,296,510	518,115	40,130	60	300	49,344,508
1895	30,960,639	1,208,482	20,236,741	441,687	44,467	50	200	52,892,266
1896	33,971,902	1,252,777	25,255,870	364,328	115,141	1,450	250	60,961,718
1897	35,230,271	1,903,411	22,805,033	388,584	147,648	65,975	500	60,541,422
1898	31,717,425	2,257,207	20,321,323	450,858	616,600	546,070	360	55,909,843
1899	33,068,356	2,642,095	20,225,356	395,838	738,183	669,013	360	57,739,201
1900	36,295,433	4,324,484	21,759,290	322,835	917,225	836,039	200	64,455,506
1901	33,618,171	8,786,330	21,933,379	465,920	989,696	4,393,658	250	70,187,404
1902	32,018,787	13,984,268	23,358,626	403,154	986,720	18,632,275	200	89,384,030
1903	31,558,248	24,382,472	24,080,264	492,885	1,573,085	18,873,343	....	100,960,297
1904	31,408,567	29,649,434	24,689,184	513,305	6,186,629	25,200,371	3,500	117,650,990
1905	29,366,960	33,427,473	22,294,171	384,692	12,533,777	37,046,605	181,084	135,234,762
1906	27,741,472	33,098,598	17,554,661	334,582	22,836,553	21,645,425	4,397,050	127,608,341
1907	25,342,137	39,748,375	13,121,094	341,190	46,846,267	16,636,610	24,281,973	166,317,646
Total	947,156,953	201,962,510	386,932,089	8,961,068	94,598,341	144,547,195	28,870,183	[a] 1,813,028,339

[a] Michigan and Missouri not included.

WELL RECORDS.

The production recorded above has resulted from the drilling of 287,922 wells, of which 232,982 were productive and 54,940 were dry holes. A distribution of these wells by fields is shown in the following table:

Wells drilled in petroleum fields in each year from 1859 to 1907.

Year.	Appalachian.		California.		Lima-Indiana.		Colorado-Wyoming.		Mid-Continent.		Gulf.		Illinois.		Total.	
	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.
1859	2	1													2	1
1860	49	39													49	39
1861	78	61													78	61
1862	92	72													92	72
1863	137	108													137	108
1864	226	180													226	180
1865	474	375													474	375
1866	442	350													442	350
1867	618	570													618	570
1868	928	208													928	208
1869	1,500	a 700													1,500	700
1870	1,664	a 800													1,664	800
1871	1,470	a 900													1,470	900
1872	1,183	a 400													1,183	400
1873	1,263	a 300													1,263	300
1874	1,317	a 200													1,317	200
1875	2,398	a 360	2												2,400	360
1876	2,920	438													2,920	438
1877	3,939	658	1												3,940	658
1878	3,064	328													3,064	328
1879	3,048	148	1												3,049	148
1880	4,217	144	3												4,220	144
1881	3,880	182	3												3,883	182
1882	3,304	179	3												3,307	179
1883	2,847	261	3												2,850	261
1884	2,205	270	4												2,269	270
1885	2,701	359	3		a 50	a 5									2,814	364
1886	3,478	525	5		a 100	a 10									3,583	535
1887	1,660	422	15		a 300	a 30	6								1,981	452
1888	1,505	371	45	30	531	27	46	24							2,127	452
1889	5,768	949	a 10	4	704	4	14	8	4		2		5		6,507	965

a Estimated.

Wells drilled in petroleum fields in each year from 1859 to 1907—Continued.

Year.	Appalachian.		California.		Lima-Ohio.		Colorado-Wyoming.		Mid-Continent.		Gulf.		Illinois.		Total.	
	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.	Completed.	Dry.
1890	6,358	1,049	a 10	5	1,969	193	2		8	2					8,347	1,249
1891	3,388	664	a 40	a 15	1,639	265	2		32	18					5,101	962
1892	1,968	462	a 60	a 20	1,741	259	2								3,771	741
1893	1,980	443	a 75	a 25	2,111	314	4								4,170	782
1894	3,763	875	a 75	a 20	3,661	565	2		50	16					7,551	1,476
1895	7,136	1,588	a 100	a 25	5,756	730	2		75	6					13,069	2,349
1896	7,824	1,901	a 175	a 30	5,638	708	34	18	137	78					13,808	2,735
1897	6,072	1,580	a 200	a 40	3,172	514	43	25	a 10	5	41	6			9,538	2,170
1898	4,792	1,269	a 275	a 50	3,088	384	103	30	a 12	a 4	374	32			8,644	1,769
1899	8,752	1,920	a 300	a 60	4,616	498	33	4	a 15	a 5	268	90			13,984	2,577
1900	8,845	2,160	a 500	a 100	5,738	662	31	13	a 30	a 10	373	98			15,517	3,043
1901	7,709	2,118	1,116	209	4,911	590	35	16	a 50	a 20	551	130			14,372	3,083
1902	7,722	2,131	422	102	6,460	725	10		293	37	a 500	a 100			15,407	3,095
1903	8,474	2,214	398	75	7,758	675	20	8	1,290	264	a 425	a 105			18,365	3,341
1904	8,859	2,383	458	158	6,897	623	25	10	3,557	475	463	186	2		20,261	3,835
1905	7,450	2,251	252	8	3,500	395	a 25	a 10	4,043	546	861	287	600	32	16,731	3,529
1906	7,568	1,934	174	7	2,743	304	a 30	a 12	3,876	501	1,081	352	3,585	500	19,057	3,610
1907	7,205	1,923	309	11	1,564	252	a 35	a 12	4,720	392	1,051	276	4,988	728	19,872	3,594
Total	174,362	39,723	5,037	994	74,647	8,732	504	190	18,202	2,379	5,990	1,662	9,180	1,260	287,922	54,940

a Estimated.

ILLUSTRATION OF THE CROWDING OF OIL WELLS, SPINDLE TOP FIELD, TEXAS.

(Photo by C. W. Hayes.)

Total number of wells in operation in petroleum fields in each year from 1859 to 1907.

Year.	Appalachian.	California.	Lima-Indiana.	Colorado-Wyoming.	Mid-Continent.	Gulf.	Illinois.	Total.
1859	1							1
1860	11							11
1861	28							28
1862	48							48
1863	77							77
1864	123							123
1865	222							222
1866	313							313
1867	351							351
1868	1,058							1,058
1869	1,838							1,838
1870	2,673							2,673
1871	3,197							3,197
1872	3,481							3,481
1873	4,752							4,752
1874	5,821							5,821
1875	7,135	2						7,137
1876	8,817	2						8,819
1877	11,234	3						11,237
1878	13,400	3						13,403
1879	15,517	4						15,521
1880	18,627	7						18,634
1881	21,158	10						21,168
1882	22,245	13						22,258
1883	22,349	16						22,365
1884	21,063	20						21,083
1885	20,729	23	[a] 45					20,797
1886	20,782	26	[a] 135					20,943
1887	17,947	37	[a] 405	6				18,395
1888	15,433	48	909	28				16,418
1889	17,127	51	1,609	34	4	2	5	18,832
1890	19,850	[a] 53	3,385	36	10	2	5	23,341
1891	20,579	[a] 74	4,759	38	24	2	5	25,481
1892	19,683	[a] 111	6,196	40	24	2	5	26,061
1893	18,267	[a] 156	7,903	44	24	2	5	26,401
1894	19,717	[a] 191	10,829	40	58	2	4	30,841
1895	24,131	[a] 251	15,251	18	127	2	4	39,784
1896	25,235	[a] 390	19,481	30	176	2	4	45,318
1897	24,418	[a] 545	20,363	46	167	37	4	45,580
1898	25,217	[a] 745	21,693	117	175	377	4	48,328
1899	30,543	[a] 945	24,329	144	185	555	4	56,705
1900	35,691	[a] 1,295	27,608	158	171	830	4	65,757
1901	38,594	2,152	28,833	175	132	1,216	4	71,106
1902	38,637	2,397	29,542	183	329	[a] 1,274	4	72,366
1903	38,974	2,575	31,695	179	1,350	[a] 1,416		76,189
1904	40,958	2,715	30,235	176	4,424	1,418	2	79,928
1905	42,634	[a] 2,734	26,315	[a] 118	7,911	1,571	570	81,853
1906	41,436	2,661	18,901	[a] 107	10,270	1,900	3,655	78,930
1907	40,033	2,559	13,130	[a] 112	14,568	2,355	7,913	80,670

[a] Estimated.

LIFE OF A WELL.

Varying with the compactness of the "pay sand" and with the pressure of the gas accompanying the petroleum, the productive life of wells varies between the extreme limits of a few months on the one hand to more than twenty years on the other. In many regions in Pennsylvania the hard and compact sandstones have resulted in wells of unusually long life, such wells having an initial production of 50 to 500 barrels in the first twenty-four hours and "settling down" to a comparatively steady production of perhaps one-tenth of that amount. This has continued for years with gradual decline, and after even twenty years many of such wells are still being pumped, with a production declining to one-tenth of a barrel per day. The other extreme, of short-lived wells, is represented by the Spindle Top type, where, from very loose sands, wells have spouted many thousands of barrels in the first twenty-four hours, have shown a correspondingly rapid decline, and have become exhausted and been abandoned within six months to four years from the time when first drilled. The experience of petroleum producers in Pennsylvania has shown seven years to be a fair average life of a well.

Adopting this average for the Appalachian, Lima-Indiana, Illinois, and Mid-Continent fields, four years for Texas, six years for California, and seven years for the minor petroleum fields, tables have been computed showing the probable number of active wells which contributed to each year's production. This has been done by adding to the existing wells all the new productive wells drilled in each year and subtracting all wells when they reached the prescribed age limit. From these tables the average daily yield of the wells of each region has been estimated:

Average production per well per day in each field from 1859 to 1907.

[Barrels of 42 gallons.]

Year.	Appalachian.	California.	Lima-Indiana.	Colorado-Wyoming.	Mid-Continent.	Gulf.	Illinois.	Average.
1859	5.48	......	......	......	......	......	......	5.48
1860	124.19	......	......	......	......	......	......	124.19
1861	206.81	......	......	......	......	......	......	206.81
1862	174.47	......	......	......	......	......	......	174.47
1863	92.91	......	......	......	......	......	......	92.91
1864	47.01	......	......	......	......	......	......	47.01
1865	30.82	......	......	......	......	......	......	30.82
1866	31.49	......	......	......	......	......	......	31.49
1867	26.13	......	......	......	......	......	......	26.13
1868	9.44	......	......	......	......	......	......	9.44
1869	6.28	......	......	......	......	......	......	6.28
1870	5.39	......	......	......	......	......	......	5.39
1871	4.46	......	......	......	......	......	......	4.46
1872	4.94	......	......	......	......	......	......	4.94
1873	5.70	......	......	......	......	......	......	5.70
1874	5.14	......	......	......	......	......	......	5.14
1875	3.37	4.11	......	......	......	......	......	3.74
1876	2.83	16.39	......	......	......	......	......	9.61
1877	3.25	11.87	......	......	......	......	......	7.56
1878	3.14	13.91	......	......	......	......	......	8.53
1879	3.51	9.28	......	......	......	......	......	6.40
1880	3.86	15.83	......	......	......	......	......	9.85
1881	3.57	27.36	......	......	......	......	......	15.47
1882	3.72	27.11	......	......	......	......	......	15.42
1883	2.86	24.46	......	......	......	......	......	13.66
1884	3.11	35.74	......	......	......	......	......	19.43
1885	2.85	38.70	2.20	......	......	......	......	14.58
1886	3.50	39.74	21.59	......	......	......	......	21.61
1887	3.49	50.24	31.46	34.83	......	......	......	30.01
1888	3.00	39.30	29.10	29.04	......	......	......	25.11
1889	3.58	16.28	20.75	25.50	.35	.07	.80	9.62
1890	4.15	15.88	12.20	28.07	.34	.08	.50	8.75
1891	4.77	11.98	10.05	47.98	.16	.08	.36	10.77
1892	4.64	9.50	7.00	56.29	.24	.06	.28	11.14
1893	4.70	8.26	5.54	37.01	2.05	.07	.22	8.26
1894	4.23	10.12	4.38	35.49	1.89	.08	.20	8.06
1895	3.52	13.19	3.64	67.23	.96	.07	.13	12.68
1896	3.68	8.78	3.54	33.10	1.79	1.98	.18	7.58
1897	3.95	9.57	3.07	23.14	2.43	4.89	.35	6.77
1898	3.45	8.30	2.57	10.56	9.65	3.97	.25	5.54
1899	2.97	7.66	2.28	7.53	10.93	3.30	.25	4.99
1900	2.79	9.15	2.16	5.60	14.70	2.76	.13	5.33
1901	2.39	11.19	2.08	7.29	20.54	9.90	.18	7.65
1902	2.27	15.99	2.17	6.04	8.22	40.07	.13	10.70
1903	2.22	25.94	2.07	7.54	3.19	36.51	......	11.07
1904	2.10	29.84	2.23	7.97	3.82	48.56	4.80	14.19
1905	1.89	33.49	2.32	8.93	4.34	64.61	.87	16.64
1906	1.83	34.07	2.54	8.57	6.09	31.21	3.30	12.52
1907	1.73	42.56	2.74	8.35	8.81	19.35	8.37	13.13
Average	18.11	20.47	7.73	23.62	5.29	14.08	1.12	......

DURATION.

PRODUCTION CURVE.

The rate of petroleum production, graphically portrayed in the curve already referred to, shows that beginning with 1860 as much petroleum has been produced in each nine years as the entire product preceding this nine years. Continuing this rate of increase the next nine years would produce 1,800,000,000 barrels, making the total amount extracted up to 1916 3,600,000,000 barrels. In 1925 the amount extracted would reach 7,200,000,000, and in 1934 14,400,000,000 barrels, and nine years more, 1943, would bring the total to almost the maximum amount estimated as obtainable from the present fields. Concerning the probability of such a rate of increase in production, one must consider the causes for the great increase in past years. The vital factor has been the ease with which any quantity of oil could be sold for cash at any time and for prices ordinarily much above the cost of production. This ready market has not been seriously disturbed even by the greatly increased production of the past few years. The second reason is based upon the liquid character of the product. With the discovery of each new field the territory is divided into many leaseholdings, frequently small in size. In pumping from one lease petroleum is apt to flow in from a rival interest. It is therefore necessary for each lessee to " get his share " before it flows away to drained territory. It is impossible to prevent the consequent rapid depletion of a field without a combination of all the interests, or by limiting by statute the amount that each producer shall extract per acre within a specified time. General industrial conditions have had little effect in regulating the production of petroleum, as has been the case with coal. The purchaser for cash has always been on hand. Even if the price paid has been low, it has been above the cost of production. The surplus has been readily marketed abroad, or burned as a substitute for coal.

Oil's independence of industrial conditions is also shown by the inability of the production to respond to greatly increased trade demand. It requires the development of new territory to greatly increase the production. Otherwise the developed fields rapidly fall into the stage of decline, which is more or less rapid as the oil sands are loose or compact. Without the opening of new territory there is no probability of continuing the indicated rate of increase. The production of the present year could not be maintained beyond a very few years. The duration of the supply will thus be extended, but with a production inadequate to legitimate demands, as the production in the past has been excessive.

Under conditions of an insufficient supply, the relations of price to production must more closely follow supply and demand, the conditions governing which have been pointed out in connection with our better known supply of coal, but there must always remain the exceptional feature of rival producers vieing in the extraction of petroleum from the same reservoir.

RAPIDLY DECLINING FIELDS.

The production tables show that in seventeen years Pennsylvania and New York have decreased to a third of their greatest output.

The decline has become quite regular, and, logically extended, will render the production negligible in ten years. The production per well per day has fallen from a maximum average of 207 barrels to 1.7 barrels, showing that increasing the number of wells is not significantly effective in stimulating the product. In fact, many very old wells are contributing to the product with as little as one-tenth of a barrel per day.

The production in West Virginia has declined to 56 per cnt of the maximum output, and new developments of great magnitude are not looked for. This State is also in the rapidly declining class.

The rate in Kentucky and Tennessee is not easily predicted, but there is no territory which has yet been proved to rank among the great producers. Ohio and Indiana are declining more rapidly at present than Pennsylvania. In Texas the decline is also rapid, and a total of only 200,000,000 barrels is estimated from the present pools. In Kansas the decline has been rapid and the production has now reached a small fraction of the previous yield and a stage where the future decline will be slower.

INCREASING TERRITORY.

Illinois and Oklahoma, in the Mid-Continent field, and California can be expectd to show greater yields. In Illinois the limitations of the new fields have not been reached, and the possibilities of considerable extensions render an increase in the yield probable for several years. The same is true in Oklahoma, particularly in the so-called "shallow pool."

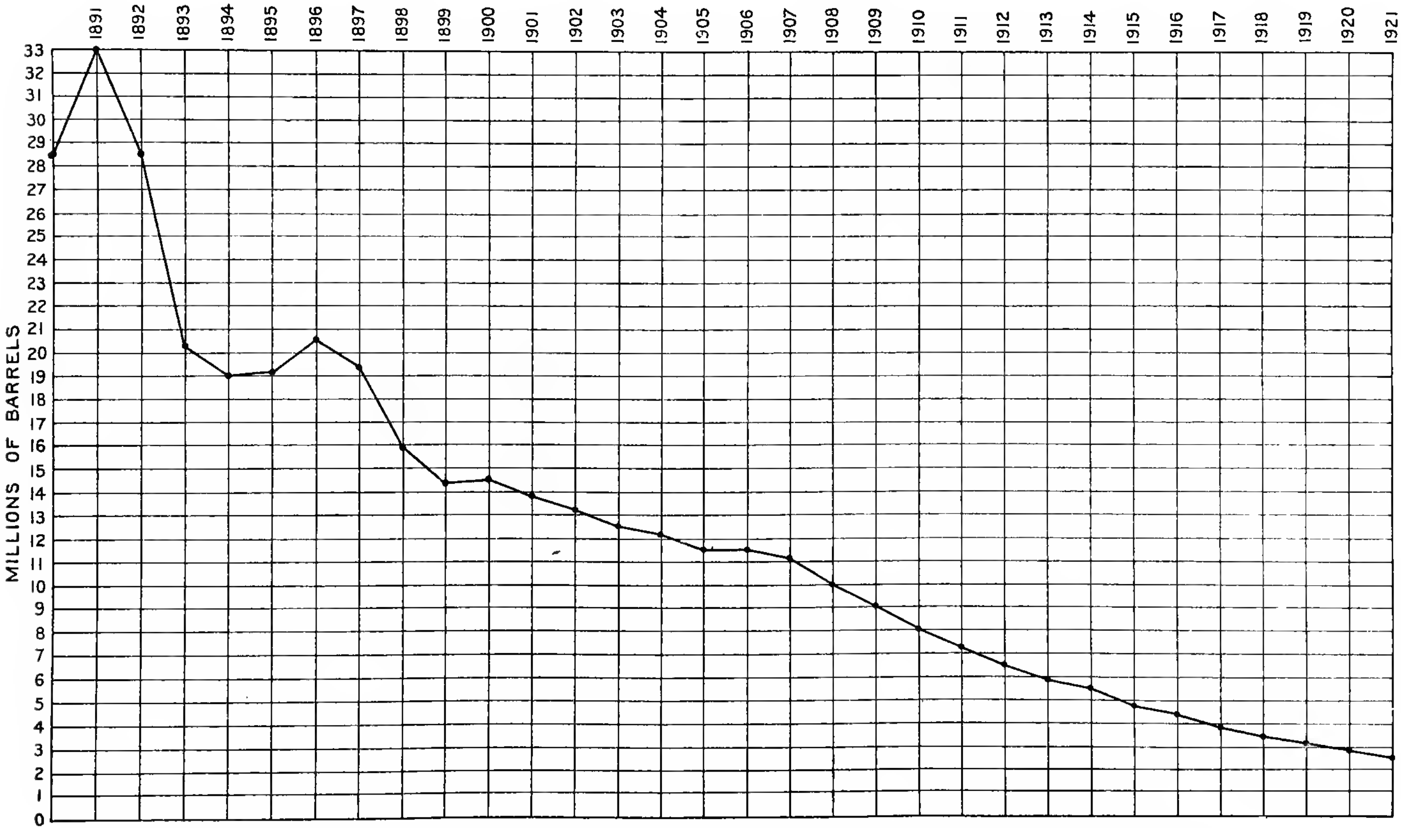
TIME OF EXHAUSTION.

Regarding the limits of time within which the present supply will be exhausted, it is clear that considering the minimum quantity of petroleum in the United States as 15,000,000,000 barrels, and continuing the present rate of increase in production, the supply would be exhausted about 1935. If the present annual production were continued without increase, 90 years would be required to exhaust this estimated minimum quantity. A reasonable view of the situation makes it probable that the present annual rate of production will be increased slightly through the developments of Illinois, Oklahoma, and California, but that within a very few years a marked decline will be noted, and this will continue with increasing value for the oil product and an insufficient quantity for the legitimate demands of the industry after another decade, and that the production, on a reduced scale, will continue for a long time, but in an amount unsatisfactory to industrial necessity, except as supplemented from new fields.

NATURE AND EXTENT OF WASTE IN THE EXTRACTION OF PETROLEUM.

STORAGE.

Waste, as understood in the natural-gas industry, has been markedly absent with petroleum. Very rarely has it proved impossible to furnish storage for some exceptionally prolific gusher. In 1907 lack



DECLINE IN PRODUCTION OF THE NEW YORK AND PENNSYLVANIA OIL FIELDS AND ITS PROBABLE RATE IN THE FUTURE.

of storage in the Mid-Continent field resulted in wasting a large amount of petroleum, estimated at 1 per cent of the total production, for which no storage was available. A similarly exceptional waste resulted in 1901 from the unexpected gushers in the Spindle Top pool in Texas.

LACK OF FORESIGHT ABROAD.

The record of the United States in providing sufficient storage in steel tanks is far better than that of the other petroleum fields of the world. In Russia lack of foresight in opening unusually strong gushers has not only led to repeated enormous waste of petroleum, but to fires which have involved the destruction of large cities. Nowhere else in the world have the emergencies of the petroleum production been met with the keen foresight and prompt treatment characteristic of the United States.

EVAPORATION.

Another form of waste of petroleum products of Europe and of the East, which has been avoided in the United States, is evaporation of gasoline and of similar light products when the petroleum is exposed to the air in open tanks. These light products form the most valuable portion of petroleum. A thin layer of any ordinary light crude petroleum will become heavy and valueless by exposure to the sun for a single day. This has been a source of great loss in the open earthen tanks which have been much used in Russia. In the United States, on the other hand, only under very exceptional circumstances has the earthen tank been used, and then only pending the completion of steel tankage. The rapidity with which steel tanks, often holding as much as 55,000 barrels, have been constructed, to the extent of farms of these tanks, is a remarkable tribute to the engineering skill of the oil-transportation companies. It is due, also, to the conditions of the iron industry, which make it possible to furnish suitable steel promptly for such emergencies. On an average, one tank per day was completed in the Mid-Continent field in 1907.

WASTE IN THE USE OF PETROLEUM.

The principal waste in the petroleum industry is connected with its utilization. In the face of an approaching scarcity, the use of petroleum should be limited to the purposes for which it is essential and for which no other material can be substituted.

ESSENTIAL USES.

Petroleum may be regarded as indispensable for the lighting of isolated houses, and for every small establishment not in connection with a gas or electric supply. The prices at which lamp oils can be sold are lower than the prices of any substitute under isolated conditions. The economic necessity, therefore, of securing the greatest amount of illuminating oil from crude petroleum is evident.

ABSOLUTE NECESSITY OF OIL FOR LUBRICATION.

A still more essential use of petroleum is for lubricating all bearings in every kind of machinery. This is necessary in the development of power by any means. The following table gives some indication of the amount of lubricating oil consumed in various kinds of power production. At least one-half pint of lubricating oil is used for every ton of coal converted into power, and when this power is carried further to its ultimate uses, such as the moving of railroad cars, and when account is taken of the machinery depending on hand power, including sewing machines, clocks, watches, etc., this necessary oil is probably doubled in amount. The conservation, therefore, of a proportionate amount of lubricating oil, consistent with all industrial activity, must become a part of the general plan for civilized progress. It should be noted that from 10 to 15 per cent is as large an amount of lubricating oil as is now obtained from crude petroleum.

Average amount of lubricating oil required for power.

	Gallon of oil per ton of coal.	Gallon of oil per horse-power day.	
Street railway power station	0.168	0.0021	Including crank case, cylinder, and engine oil.
Niagara Falls power house	.024	.0003	Doubtless supplemented by water lubrication.
Fleet of 167 steam vessels, total indicated horsepower, 480,900.	.209	.0025	Machine and cylinder oil.
New England industrial plants:			
No. 1	.400	.0048	Cylinder oil.
No. 2	.200	.0024	
No. 3	.670	.0080	
No. 4	.500	.0060	
Average	.310	.0037	

UNNECESSARY USES.

In 1907 there were 18,855,691 barrels of crude petroleum burned as fuel in locomotives, and a large proportion of the California production was used for the development of power, principally by burning it for the generation of steam. Whenever a large increase is made in the production of petroleum with a corresponding decrease in price, the producers are grateful for any outlet for their oil and sell it for such low-grade uses, in which it brings not more than one hundredth part and has brought as low as one thousandth part of the maximum price for high-grade petroleum products. Much of this crude petroleum, had it remained stored in the ground, could later have been converted into far more valuable products. Much petroleum has been used for oiling roads. The skillful application of petroleum residues to poor road surfaces has proved so effective that this use is justifiable, but the use of crude petroleum for such purposes can seldom be considered in any other light than as a waste, especially as coal-tar residues and waste products of the coking and illuminating-gas industry serve this purpose well enough.

EXPORTS.

The greatest waste of petroleum has been in exporting crude petroleum and petroleum products to foreign countries. The necessity for it has been due to the sudden increase of production, due to the discovery and immediate development of the larger fields, and only by this means has it been possible for the producers to continue the practice of furnishing a constant market for petroleum, wherever produced. This immediate purchase of the product has meant a gain of millions of dollars to the producers.

METHODS OF PREVENTING OR LESSENING WASTE IN THE PETROLEUM INDUSTRY.

CHECKING UNNECESSARY PRODUCTION.

At present, more petroleum is being produced than is necessary for the legitimate demands of the industry. Within ten years the present fields will be unable profitably to produce enough for these legitimate requirements. Inasmuch as the lands now owned by private interests are leased by rival concerns, it is impossible to prevent each rival from producing petroleum as rapidly as he desires. The only direction in which production can be checked is with the petroleum contained in public lands. Offering such public land for entry at a nominal price is nothing more than temptation to the private citizen to waste petroleum by overproduction, since lands yielding hundreds of dollars per acre in this product can be obtained for a nominal sum. Every acre of public land believed to contain supplies of petroleum or natural gas should be withdrawn from every form of entry and should be subjected to an equitable system of lease. By this means undoubtedly a large amount of petroleum would be reserved for use when the supply becomes inadequate to industrial demands. It should be noted that since the advance copies of this report appeared in the public press, the petroleum producers of Oklahoma have arranged to reduce production in that State.

BETTER COMBUSTION.

The use of petroleum as a form of power is justified on the Pacific coast, provided attention is given to securing the maximum amount of power per unit of oil. This is not consistent with burning oil under stationary boilers for the production of steam, but prompt study should be given to the development of internal-combustion engines capable of using crude petroleum or, more particularly, less valuable residuum. It should be noted that private enterprise has already done much for the successful solution of this problem.

HOW SUPPLIES OF PETROLEUM MAY BE EXTENDED.

PREVENTION OF WASTE IN EXTRACTION AND IN USE.

Legislation tending to the capping of gas wells in petroleum fields, to preserve the pressure, and to prevent the unnecessary encroachment of water, should be extended to all States where petroleum is produced. After the practical exhaustion of the field by this encroachment of water, the remaining petroleum can frequently be washed into smaller but still profitable pools—a system which is already intelligently used in this country.

DISCOVERY AND DEVELOPMENT OF SUBSTITUTES.

Alcohol from grain, potatoes, and waste products can be used in the place of petroleum as an illuminant and for power in place of gasoline whenever the necessity arises. No practical substitute is known for mineral lubricating oils. Animal and vegetable oils are excluded as entirely too expensive. The production of artificial petroleum from various vegetable and animal waste products has received sufficient study to indicate the possibility of good results if scientific research is encouraged in this direction.

NECESSITY OF SCIENTIFIC RESEARCH.

The most practical recommendation seems to be the encouragement of scientific research in the study of the conditions of occurrence of petroleum in the earth, in order to lessen the expense of discovery of new pools. A second line of scientific research of even greater value should include fundamental studies of the nature of all kinds of petroleum, with a view to converting less valuable varieties into higher grades and to producing greater proportions of the absolutely necessary lubricating oils from crude petroleum. Such scientific study should be initiated at once to be of benefit when the present petroleum supply becomes inadequate.

RECOMMENDATIONS.

Three conclusions are self-evident from this report.

First. It is absolutely necessary for the preservation of an adequate supply of petroleum that all public lands where petroleum is probable should at once be withdrawn from entry.

Second. A general investigation of the conditions of accumulation of petroleum and its geographic distribution should be undertaken in order that the petroleum-bearing public lands may be selected.

Third. Fundamental scientific study of the nature of petroleum, especially with a view to securing the greatest yields of the most valuable constituents and even for transmuting one oil into another, is required for its most intelligent use.

NATURAL-GAS RESOURCES OF THE UNITED STATES.

By David T. Day,
United States Geological Survey.

THE GAS FIELDS.

DISTRIBUTION.

The conditions favorable to the accumulation of gas reservoirs are in general the same as for petroleum. The two usually overlap. More or less gas is always found dissolved in crude petroleum, and the amount of gas obtained at a given pressure from a sand of slight thickness leads to the belief that the gas is dissolved in the petroleum under pressure, in a manner similar to the solution of carbonic acid in water. Reservoirs filled with dry gas are often found—almost always in the neighborhood of petroleum fields—though beds of coal often yield natural gas, even when far from oil wells, as in the anthracite mines of Pennsylvania, where gas is found more than 100 miles distant from any petroleum pool.

AREAS.

The areas shown on the petroleum and gas map, accompanying this report, comprise the regions in which either natural gas or petroleum is the more valuable product. The limits of these areas have been revised since the map was published, and they now show the following measurements in square miles:

State.	Square miles.	State.	Square miles.	State.	Square miles.
Alabama	40	Missouri	70	South Dakota	80
California	310	Montana	40	Texas	130
Colorado	80	New York	550	Utah	40
Illinois	50	Ohio:		Washington	70
Indiana	2,460	Eastern	110	West Virginia	1,000
Kansas	550	Western	165	Wyoming	120
Kentucky	290	Oklahoma	1,000		
Louisiana	110	Oregon	20	Total	10,055
Michigan	40	Pennsylvania	2,730		

PRESSURE.

Estimates of the total yield, in cubic feet, which can be expected from the gas pools are ordinarily obtained by measuring the pressure with a Pitot tube, calculating by a simple formula the cubic feet per day, and observing the rate of decline.

The closed or rock pressures in various fields, in so far as reliable records are available, are given in the following table for various years:

Pressure of natural gas in various fields at various dates.

[In pounds per square inch.]

	Illinois.	Indiana.	Kansas.	Kentucky.	New York.	Ohio.	Oklahoma.	Pennsylvania.	Texas.	West Virginia.
1885	400-450					450		150-575		
1886	125	325-400	110			400		200-460		550-680
1887		320-340				[a]750 [b]650		200-380		
1888	300	325		125		[b]450				
1889		325			400	250-390				
1890					240	170-275				1,000
1893		280								
1894	60	260	200					250		
1895	40	240		[c]60 [d]250-300		[b]50-150		150		
1896	25	220	100	285-300		[a]750 [b]45		85		600-900
1897		195	250		1,500	[b]30				100-1,100
1898		165								600-1,200
1899	[e]3-30	150	300-325		200					1,200
1900		110	[f]310-320 [g]150			[a]300-400 ([b] [h])				1,200
1901		80							[i]250	1,000-1,300
1902		50				[a]100 [j]800				1 000-1,250
1903								400		850-1,250
1904		155 [k]305-400	550-650							
1906	150-435	22-156	90-282		45-335	121-352	217-468	41-486		144-516

[a] Lancaster.
[b] Northwestern Ohio.
[c] Western Kentucky.
[d] Eastern Kentucky.
[e] Bureau County.
[f] Allen County.
[g] Neosho County.
[h] Reduced to almost no pressure.
[i] Beaumont.
[j] Homer.
[k] Southern Indiana.

The paucity of actual data is evident from the table above. It is useful only in showing the generally rapid decline of the high pressures.

PRODUCTION.

The following tables show the value of the natural gas thus far produced. It has been possible only in the last two years to determine the quantity, in addition to the value of gas produced, but this shows that the quantity produced, as well as the price, is increasing.

Approximate value of natural gas produced in the United States, 1882–1907, by States.

State.	1882.	1883.	1884.	1885.	1886.	1887.
Pennsylvania	$75,000	$200,000	$1,100,000	$4,500,000	$9,000,000	$13,749,500
New York				196,000	210,000	333,000
Ohio				100,000	400,000	1,000,000
West Virginia				40,000	60,000	120,000
Illinois				1,200	4,000	
Indiana					300,000	600,000
Kansas					6,000	
Other	140,000	275,000	360,000	20,000	32,000	15,000
Total	215,000	475,000	1,460,000	4,857,200	10,012,000	15,817,500

Approximate value of natural gas produced in the United States, 1882–1907, by States—Continued.

State.	1888.	1889.	1890.	1891.	1892.	1893.
Pennsylvania	$19,282,375	$11,593,989	$9,551,025	$7,834,016	$7,376,281	$6,488,000
New York	332,500	530,026	552,000	280,000	216,000	210,000
Ohio	1,500,000	5,215,669	4,684,300	3,076,325	2,136,000	1,510,000
West Virginia	120,000	12,000	5,400	35,000	70,500	123,000
Illinois	....	10,615	6,000	6,000	12,988	14,000
Indiana	1,320,000	2,075,702	2,302,500	3,942,500	4,716,000	5,718,000
Kansas	....	15,873	12,000	5,500	40,795	50,000
Missouri	....	35,687	10,500	1,500	3,775	2,100
California	....	12,680	33,000	30,000	55,000	62,000
Kentucky and Tennessee	....	2,580	30,000	38,993	43,175	68,500
Texas and Alabama	....	1,728	....	....	100	50
Arkansas and Wyoming	....	375	....	250	100	100
Utah	....	....	....	....	....	500
Other	75,000	1,600,175	1,606,000	250,000	200,000	100,000
Total	22,629,875	21,107,099	18,792,725	15,500,084	14,870,714	14,346,250

State.	1894.	1895.	1896.	1897.	1898.	1899.	1900.
Pennsylvania	$6,279,000	$5,852,000	$5,528,610	$6,242,543	$6,806,742	$8,337,210	$10,215,412
New York	249,000	241,530	256,000	200,076	229,078	294,593	335,367
Ohio	1,276,100	1,255,700	1,172,400	1,171,777	1,488,308	1,866,271	2,178,234
West Virginia	395,000	100,000	640,000	912,528	1,334,023	2,335,864	2,959,032
Illinois	15,000	7,500	6,375	5,000	2,498	2,067	1,700
Indiana	5,437,000	5,203,200	5,043,635	5,009,208	5,060,969	6,680,370	7,254,539
Kansas	86,600	112,400	124,750	105,700	174,640	332,592	356,900
Missouri	4,500	3,500	1,500	500	145	290	547
California	60,350	55,000	55,682	50,000	65,337	86,891	79,083
Kentucky and Tennessee	89,200	98,700	99,000	90,000	103,133	125,745	....
Alabama }	50	20			765	8,000	{ ....
Texas }			....	....			20,000
Arkansas and Wyoming	100	100	60	40	....	....	....
Utah	500	20,000	20,000	15,050	7,875	....	....
Kentucky	....	....	....	....	....	....	286,243
Colorado	12,000	7,000	4,500	4,000	3,300	1,480	1,800
South Dakota	....	....	....	....	....	3,500	9,817
Other	50,000	50,000	50,000	20,000	20,000	....	....
Total	13,954,400	13,006,650	13,002,512	13,826,422	15,296,813	20,074,873	23,698,674

State.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
Pennsylvania	$12,688,161	$14,352,183	$16,182,834	$18,139,914	$19,197,336	$18,558,245	$18,844,156
New York	293,232	346,471	493,686	522,575	623,251	672,795	766,157
Ohio	2,147,215	2,355,458	4,479,040	5,315,564	5,721,462	7,145,809	8,718,562
West Virginia	3,954,472	5,390,181	6,882,359	8,114,249	10,075,804	13,735,343	16,670,962
Illinois	1,825	1,844	3,310	4,745	7,223	87,211	143,577
Indiana	6,954,566	7,081,344	6,098,364	4,342,409	3,094,134	1,750,715	1,572,605
Kansas	659,173	824,431	1,123,849	1,517,643	2,261,836	4,010,986	4,843,019
Missouri	1,328	2,154	7,070	6,285	7,390	7,210	17,010
California	67,602	120,648	104,521	114,195	133,696	134,560	168,397
Alabama	....	....	....	} 14,082	14,409	}	
Texas	18,577	14,953	13,851	}		} 150,695	178,276
Louisiana	....	....	....	....	1,500	}	
Kentucky	270,871	365,356	390,301	322,104	237,290	287,501	380,176
Tennessee	....	300	300	300	300	300	300
Arkansas and Wyoming	....	....	2,460	6,515	21,135	34,500	} 126,582
Colorado	1,800	1,900	14,140	14,300	20,752	22,800	}
South Dakota	7,255	10,280	10,775	12,215	15,200	15,400	19,500
Oklahoma	....	360	1,000	49,665	130,137	259,862	417,221
North Dakota	....	....	....	....	....	....	235
Oregon	....	....	....	....	....	....	100
Total	27,066,077	30,867,863	35,807,860	38,496,760	41,562,855	46,873,932	52,866,835

Value of natural gas consumed in the United States, 1902–1907, by States.

State.	1902.	1903.	1904.	1905.	1906.	1907.
Pennsylvania	$13,942,783	$16,060,196	$17,205,804	$19,237,218	$21,085,077	$22,917,547
Ohio	4,785,766	7,200,867	9,393,843	10,396,633	12,652,520	15,227,780
Kansas	824,431	1,123,849	1,517,643	2,265,945	} 4,030,776	4,853,298
Missouri	2,154	7,070	6,285	7,390		17,010
West Virginia	2,473,174	3,125,061	3,383,515	3,586,608	3,720,440	3,757,977
New York	1,723,709	1,944,667	2,222,980	2,434,894	2,654,115	3,098,533
Indiana	[a] 6,710,080	[a] 5,915,367	[a] 4,282,409	[a] 3,056,634	[a] 1,750,755	1,570,605
Kentucky	255,481	280,426	268,264	237,290	287,501	380,176
Oklahoma	360	1,000	49,665	126,028	247,282	406,942
Alabama	....	....	} 14,082		}	
Texas	14,953	13,851		14,409	150,695	178,276
Louisiana	....	....	....	1,500		
California	120,648	104,521	114,195	133,696	134,560	168,397
Illinois	1,844	3,310	4,745	7,223	87,211	143,577
Arkansas	....	} 2,460	6,515	21,135	34,500	}
Wyoming	....					126,582
Colorado	1,900	14,140	14,300	20,752	22,800	
South Dakota	10,280	10,775	12,215	15,200	15,400	19,500
Tennessee	300	300	300	300	300	300
North Dakota	....	....	....	....	....	235
Oregon	....	....	....	....	....	100
Total	30,867,863	35,807,860	38,496,760	41,562,855	46,873,932	52,866,835

[a] A portion of this was consumed in Chicago, Ill.

Distribution of natural gas consumed in the United States in 1906, by States.

State.	Number of producers.	Consumers.		Gas consumed.		
				Domestic.		
		Domestic.	Industrial.	Quantity, M cubic feet.	Cents per M cu. ft.	Value.
Pennsylvania	309	273,184	3,307	41,135,808	22.2	$9,128,837
Ohio	409	310,175	3,316	33,049,479	24.7	8,165,567
Kansas	130	} 79,512	995	9,576,572	17.5	1,673,979
Missouri	19					
West Virginia	67	51,281	913	9,619,147	15.5	1,489,473
New York	143	74,538	95	8,999,871	27.7	2,495,040
Indiana	578	47,368	156	5,049,759	27.8	1,403,987
Kentucky	45	17,216	18	679,941	40.5	275,860
Oklahoma	50	8,391	202	1,446,879	11.8	170,774
Alabama	2	1	1	}		
Louisiana	4	2,700	28	273,919	30.4	83,320
Texas	5	702	1			
California	18	5,537	10	122,577	97.3	119,338
Illinois	66	1,429	2	359,556	22.8	82,211
Arkansas	4	1,700	4	} 58,500	49.1	28,711
Wyoming	3	3	4			
Colorado	3	800	11	20,500	100.0	20,500
South Dakota	13	406	10	12,900	88.4	11,400
Tennessee	3	1	1	400	25.0	100
Total	1,871	874,944	9,074	110,405,808	22.7	25,149,097

Distribution of natural gas consumed in the United States in 1906, by States—Continued.

State.	Gas consumed.					
	Industrial.			Total.		
	Quantity, M cubic feet.	Cents per M cu. ft.	Value.	Quantity, M cubic feet.	Cents per M cu. ft.	Value.
Pennsylvania	120,959,365	9.9	$11,956,240	162,095,173	13.0	$21,085,077
Ohio	41,763,083	10.7	4,486,953	74,812,562	16.9	12,652,520
Kansas, Missouri	59,891,889	3.9	2,356,797	69,468,461	5.8	4,030,776
West Virginia	48,835,862	4.6	2,230,967	58,455,009	6.3	3,720,440
New York	1,182,551	13.4	159,075	10,182,422	26.0	2,654,115
Indiana	2,811,781	12.3	346,768	7,861,540	22.2	1,750,755
Kentucky	109,213	10.6	11,641	789,154	36.4	287,501
Oklahoma	1,961,249	3.9	76,508	3,408,128	7.2	247,282
Alabama, Louisiana, Texas	764,650	8.8	67,375	1,038,569	14.5	150,695
California	30,444	50.0	15,222	153,021	87.9	134,560
Illinois	50,000	10.0	5,000	409,556	21.3	87,211
Arkansas, Wyoming	62,000	9.3	5,789	120,500	28.6	34,500
Colorado	3,067	75.0	2,300	23,567	96.7	22,800
South Dakota	10,000	40.0	4,000	22,900	67.2	15,400
Tennessee	1,600	12.5	200	2,000	15.0	300
Total	278,436,754	7.8	21,724,835	388,842,562	12.1	46,873,932

Quantity and value of natural gas produced and consumed in the United States in 1906, by States.

State.	Produced.			Consumed.		
	Quantity, M cubic feet.	Cts. per M cu. ft.	Value.	Quantity, M cubic feet.	Cts. per M cu. ft.	Value.
Pennsylvania	138,161,385	13.4	$18,558,245	162,095,173	13.0	$21,085,077
Ohio	45,436,020	15.7	7,145,809	74,812,562	16.9	12,652,520
West Virginia	119,400,392	11.5	13,735,343	58,455,009	6.3	3,720,440
Kansas	69,322,633	5.8	4,010,986	69,468,461 (Kansas and Missouri)	5.8	4,030,776
Missouri	33,560	21.5	7,210			
New York	2,547,769	26.4	672,795	10,182,422	26.0	2,654,115
Indiana	7,861,140	22.2	1,750,715	7,861,540	22.2	1,750,755
Kentucky	789,154	36.4	287,501	789,154	36.4	287,501
Oklahoma	3,520,396	7.3	259,862	3,408,128	7.2	247,282
California	153,021	87.9	134,560	153,021	87.9	134,560
Alabama, Louisiana, Texas	1,038,569	14.5	150,695	1,038,569	14.5	150,695
Illinois	409,556	21.3	87,211	409,556	21.3	87,211
Colorado	23,567	96.7	22,800	23,567	96.7	22,800
Arkansas, Wyoming	120,500	28.6	34,500	120,500	28.6	34,500
South Dakota	22,900	67.2	15,400	22,900	67.2	15,400
Tennessee	2,000	15.0	300	2,000	15.0	300
Total	388,842,562	12.1	46,873,932	388,842,562	12.1	46,873,932

Quantity and value of natural gas consumed in the United States in 1907, by States.

State.	Number of producers.	Consumers.		Gas consumed.		
				Domestic.		
		Domestic.	Industrial.	Quantity, M cu. ft.	Cents per M cu. ft.	Value.
Pennsylvania	344	295,115	3,812	44,840,748	24.2	$10,846,922
Ohio	468	380,489	5,476	41,970,198	24.4	10,228,979
Kansas	196	146,327	1,605	16,022,597	14.8	2,374,761
West Virginia	105	53,807	1,000	9,807,000	16	1,567,911
New York	208	83,805	155	10,466,829	27.9	2,918,817
Indiana	687	46,210	218	4,480,499	28.7	1,284,160
Oklahoma	107	11,038	277	1,262,808	19.3	244,050
Kentucky	38	19,279	239	1,028,898	31.5	324,368
Alabama	2	600	4			
Louisiana	5	3,000	38	343,261	30.7	105,272
Texas	8	1,250	6			
California	51	6,346	37	97,245	102.2	99,376
Illinois	128	2,126	61	344,304	22.7	78,284
Arkansas	6	3,899	35			
Colorado	3	1,091	21	185,405	40.5	75,182
Wyoming	4	6	3			
South Dakota	13	529	5	22,500	53.8	12,100
Missouri	26	259	12	41,340	25	10,335
Tennessee	4	1	1	400	25	100
North Dakota	3	3	....	940	25	235
Oregon	1	1	....	400	25	100
Total	2,407	1,055,181	13,005	130,915,372	23	30,170,952

State.	Gas consumed.					
	Industrial.			Total.		
	Quantity, M cu. ft.	Cents per M cu. ft.	Value.	Quantity, M cu. ft.	Cents per M cu. ft.	Value.
Pennsylvania	119,700,431	10.1	$12,070,625	164,541,179	13.9	$22,917,547
Ohio	41,001,570	12.2	4,998,801	82,971,768	18.4	15,227,780
Kansas	58,555,098	4.2	2,478,537	74,577,695	6.5	4,853,298
West Virginia	44,363,520	4.9	2,190,066	54,170,520	6.9	3,757,977
New York	1,390,925	12.9	179,716	11,857,754	26.1	3,098,533
Indiana	2,134,705	13.4	286,445	6,615,204	23.7	1,570,605
Oklahoma	3,552,828	4.6	162,892	4,815,636	8.5	406,942
Kentucky	274,260	20.3	55,808	1,303,158	29.2	380,176
Alabama						
Louisiana	944,473	7.7	73,004	1,287,734	13.8	178,276
Texas						
California	133,099	51.8	69,021	230,344	73.1	168,397
Illinois	810,040	8.1	65,293	1,154,344	12.4	143,577
Arkansas						
Colorado	581,583	8.8	51,400	766,988	16.5	126,582
Wyoming						
South Dakota	15,000	49.3	7,400	37,500	52	19,500
Missouri	66,750	10	6,675	108,090	15.7	17,010
Tennessee	1,600	12.5	200	2,000	15	300
North Dakota	....	....	....	940	25	235
Oregon	....	....	....	400	25	100
Total	273,525,882	8.3	22,695,883	404,441,254	13.07	52,866,835

Quantity and value of natural gas produced and consumed in the United States in 1907, by States.

State.	Produced.			Consumed.		
	Quantity, M cu. ft.	Cents per M cu. ft.	Value.	Quantity, M cu. ft.	Cents per M cu. ft.	Value.
Pennsylvania	135,516,015	13.9	$18,844,156	164,541,179	13.9	$22,917,547
West Virginia	122,687,236	13.6	16,670,962	54,170,520	6.9	3,757,977
Ohio	52,040,996	16.8	8,718,562	82,971,768	18.4	15,227,780
Kansas	74,526,300	6.5	4,843,019	74,577,695	6.5	4,853,298
Indiana	6,624,204	23.7	1,572,605	6,615,204	23.7	1,570,605
New York	3,287,974	23.3	766,157	11,857,754	26.1	3,098,533
Oklahoma	4,867,031	8.5	417,221	4,815,636	8.5	406,942
Kentucky	1,303,158	29.2	380,176	1,303,158	29.2	380,176
Alabama, Louisiana, Texas	1,287,734	13.8	178,276	1,287,734	13.8	178,276
California	230,344	73.1	168,397	230,344	73.1	168,397
Illinois	1,154,344	12.4	143,577	1,154,344	12.4	143,577
Arkansas, Colorado, Wyoming	766,988	16.5	126,582	766,988	16.5	126,582
North Dakota	940	25.0	235	940	25.0	235
Missouri	108,090	15.7	17,010	108,090	15.7	17,010
Tennessee	2,000	15.0	300	2,000	15.0	300
South Dakota	37,500	52.0	19,500	37,500	52.0	19,500
Oregon	400	25.0	100	400	25.0	100
Total	404,441,254	13.07	52,866,835	404,441,254	13.07	52,866,835

PROBABLE DURATION OF THE SUPPLY OF NATURAL GAS.

The duration of high pressures in the known fields is very short. There is no probability of the pressures exceeding 100 pounds per well after ten years. The rate of decline is a peculiar one. At first very rapid, it would be expected that the decline in pressure would follow a simple rate, but it does not. Many wells are still showing a slight but appreciable yield by pumping them after the pressure became negligible. The yield from these low-pressure wells is surprisingly persistent. Evidently the territory drawn upon by them is much larger than was expected. The pumping of natural gas in order to utilize the entire supply is the most hopeful element in the outlook for a continued supply. It is this feature which made possible the use of a larger quantity of natural gas last year than the year before. The outlook is that natural gas will be utilized for as long a period as has already elapsed since the industry began, with the greater part to be furnished by the Mid-Continent field.

NATURE AND EXTENT OF WASTE IN THE EXTRACTION OF NATURAL GAS.

Waste of natural gas will be divided into three classes: First, waste incident to the discovery of a natural-gas field; second, waste in oil production; third, waste in consumption.

WASTE FROM HIGH-PRESSURE WELLS.

It has been a common experience in the discovery of a gas field to encounter pressures so great as to lead to great difficulty in capping, and thus confining the gas until needed. Noted instances of this were the Homewood well near Pittsburg, the Karg and Adams wells in Ohio, the Caney Fork well in Kansas, and, more recently, the wells of the Caddo field in northwestern Louisiana. Individual wells among these have wasted as much as 25,000,000 cubic feet per day, or sufficient gas to supply the entire consumption of three cities the size of Washington, D. C. In the Caddo field at the present time the waste of this character is estimated at 70,000,000 cubic feet per day. In this case wells are drilled through the gas-producing stratum in search of petroleum, which is usually found a few hundred feet below. The natural gas is cased off, but usually, owing to lack of skill on the part of the driller and indifference to the waste of gas, the gas escapes around the casing in increasing volume as the earth is loosened from around the pipe, and finally the force of the gas is sufficient to blow the casing entirely from the well. This has happened in four wells already in the Caddo field. When a well is thus "blown out" little effort has been made to close it. It has been the practice to set fire to the gas for an advertisement to the region.

WASTE OF GAS FROM OIL WELLS.

The production of more or less gas is incident to the drilling of all oil wells, and in most of them, by the time the petroleum-bearing sand is reached, the escape of gas is very great. Taken altogether, the waste of gas by this means is much greater and much more difficult to prevent than the waste from high-pressure gas wells.

In the first days of oil-well drilling in Pennsylvania, natural gas was a nuisance and a menace to the oil producer. This menace became greater with the volume of the gas. It developed a hostility toward natural gas on the part of the oil-well driller, which has increased rather than diminished up to the present time. It is to this hostility that the present waste of natural gas in oil regions is due. When natural gas was encountered in a sand above the expected oil stratum, it always cost considerable money to case it off and pack it in order to continue the drilling, and frequently caused explosions, tearing out the side of the well and occasionally blowing out the casing, causing the ruin of the enterprise. Every oil well now drilled includes in its outfit pipes connected with the casing for carrying the natural gas to a safe distance. Frequently it is burned to get rid of it, sometimes under the boiler to supply power for the well drilling and pumping. This practice has become so general that it is a common custom to pay $5 per twenty-four hours for the power for a well-pumping station. When the natural gas contains appreciable amounts of hydrogen sulphide, with the consequent injury to health, its presence is proportionately less welcome.

It is difficult for the oil-well driller to obtain a prompt and profitable market for the natural gas, whereas with oil it is only necessary to connect the well to a tank, and the cash for the product can be obtained within a few hours. Occasionally, when the pressure due to natural gas is greatly relieved, oil is found. The oil-well driller has accepted this exceptional case as a rule, and is apt to give all possible vent to the gas in the hope of its being followed by the desired petroleum. As to the amount of natural gas which is being wasted daily, no accurate statistics have been attempted, and the judgment of Dr. I. C. White,[a] state geologist of West Virginia, may well be accepted,

[a] Conference on the conservation of natural resources, White House, "Waste of fuel resources," p. 5.

to the effect that no less than 1,000,000,000 cubic feet of gas are wasted every twenty-four hours. Of this undoubtedly the larger part is wasted in the production of oil. Pumping the oil leaves the wells more or less open, and prevents any careful saving of the gas.

WASTE IN CONSUMPTION.

Directly associated with the waste of natural gas by allowing it to escape freely from oil and gas wells is the form of waste where the gas is used, by delivering it through pipes back into the ground in oil wells below the oil-bearing stratum, so that it will spray the oil to the surface. The mixture of oil and gas then runs into a tank where the oil is saved, but usually the gas is allowed free vent to the outside air. The lack of care in saving the gas after thus using it is a good example of the carelessness with this material prevalent in the oil fields.

Where natural gas is utilized for power, heat, and the lighting of dwellings and has once entered the pipe lines of the distributer, the waste is comparatively small, and little can be said at the present time in regard to any serious loss due to ineffective consumption. Much is used for lighting with incandescent mantles, an efficient use which leaves practically nothing to be desired. A still greater quantity is burned in stoves or in grates, under conditions which are also efficient. For power purposes there is little excuse for burning gas under boilers for the generation of steam, when so much greater economy can readily be produced by consuming it in internal-combustion engines, and the adoption of the gas engine in the place of steam should proceed with far greater rapidity than at present. The following table, prepared by Dr. F. H. Oliphant in 1892,[a] shows that nine-tenths of all the gas used could be saved by substituting internal-combustion engines for the kind of steam engines in use in the oil regions.

Comparison of fuel per indicated horsepower per hour for different types of engines.

Type of engine.	Cubic feet of gas.
Large natural-gas engine, highest type	9
Ordinary natural-gas engine	13
Triple-expansion condensing steam engine	16
Double-expansion condensing steam engine	20
Single-cylinder and cut-off steam engine	40
Ordinary high pressure, without cut-off, steam engine	80
Ordinary oil well pumping steam engine	130

METHODS OF PREVENTING OR LESSENING THE WASTE OF NATURAL GAS.

What has been said above concerning the substitution of gas engines supplied with natural gas, instead of burning natural gas under steam boilers, is a matter of small moment compared with the prevention of escape of natural gas into the air. Our total consumption of natural gas in the United States in 1907 was 404,000,-000,000 cubic feet per year, whereas the amount wasted—not burned

[a] Mineral Resources, 1892.

at all—was estimated at practically the same amount. Thus only half of all the natural gas actually produced goes to any useful purpose. This waste should furnish light for half the urban population of the United States. Remedy for this waste by legislation has been extremely effective in Indiana, Ohio, and Pennsylvania. Only a part of the credit for stopping natural-gas waste is due to legislation, much credit being due to the natural-gas companies themselves for taking the initiative in this reform and carrying it out with most commendable vigor. As a result, the waste of natural gas in these States has practically ceased. Great precautions are now used for the suppression of every flambeau or open gaslight. They are only to be seen at the present time occasionally in connection with the drilling of oil wells. These precautions in late years have not been due so much to legal restrictions as to the efforts of the natural-gas distributers to economize in every direction in the saving of natural gas. The laws of Pennsylvania, West Virginia, Ohio, and Indiana call for the efficient capping of every natural-gas well when not in use. This, however, does not prevent the escape of natural gas where it is an incident of oil production. In this field a more practical plan will depend on the cooperation of the natural-gas and oil-collecting companies, by which the oil producer may receive pay promptly for natural gas to be collected by the natural-gas companies from his oil well. In West Virginia the oil-collecting companies and the natural-gas collecting companies are usually simply branches of the same company, and this plan of collecting gas from the oil wells is already being carried into effect. The ingenuity and watchfulness of the natural-gas companies has effected far greater saving in natural gas than was believed possible five years ago. The result is in evidence from the gain in production in Pennsylvania and West Virginia, where high pressures have practically ceased.

EXTENSION OF NATURAL-GAS SUPPLIES.

PREVENTION OF WASTE IN EXTRACTION AND IN USE.

It is of prime necessity that the laws concerning the capping of natural-gas wells, which have had such good effect in the principal oil and gas producing States, should be extended to the newer fields in the Southern and Southwestern States, and that the most radical measures should be taken to promptly suppress the great waste in these fields at the present time. When effective laws are in operation controlling the escape of gas from high-pressure wells, the problem will be reduced to saving the gas from the oil wells—a problem which can be solved only by affording a prompt and efficient market for the gas, even when produced in small quantity. Meantime, the problem of compressing natural gas in steel cylinders for small-scale transportation is receiving much consideration. Within the next few years success will undoubtedly be attained in returning the natural gas to reservoirs within the earth, which have proved to be sufficiently tight to hold the gas under heavy pressure. Experiments in this direction, costing more than $125,000, are being carried out in Ohio.

INCREASING EFFICIENCY IN USE.

This has already been sufficiently referred to in a previous paragraph.

DISCOVERY AND DEVELOPMENT OF SUBSTITUTES.

Unlike petroleum, natural gas can be replaced efficiently, at least for all practical purposes, by fuel gases produced by methods which are already well understood and are being studied with great care by the technologic branch of the United States Geological Survey. This substitution of fuel gas is well understood. The replacement of the artificial gas for the natural will regularly follow the trade relation of price. It is known that many large culm banks and other amounts of refuse coal are already owned by the natural-gas companies in anticipation of their utilization at the place where they occur, for making and distributing gas to distant points of consumption. This long-distance transportation of natural gas has been developed on so large a scale between West Virginia and Cleveland, Ohio, that the transmission of fuel gas over long distances is now also being studied as a certain feature of future industrial progress.

PEAT RESOURCES OF THE UNITED STATES EXCLUSIVE OF ALASKA.

By Charles A. Davis,
United States Geological Survey.

Peat as a source of fuel and power, as well as the raw material upon which may be based a number of industries, has but recently attracted general attention in this country. It has, however, long been used in northern Europe, where it is estimated that in the neighborhood of 10,000,000 tons prepared in various ways are consumed as fuel annually, and smaller amounts are used as stable litter, for sanitary purposes, and in various trades and arts.

It has been assumed by engineers, economists, economic geologists, and others, because of the abundance and cheapness of good coal and wood in the United States, that peat could not be used profitably in competition with them, at least for a long time to come.

Recent developments in the utilization of low-grade fuels in producer-gas engines, and the very considerable successful use of peat for the generation of fuel, illuminating and producer gas in Sweden, Germany, Russia, and other countries of Europe, have made a marked impression on those scientists and others in America who have followed the march of events in this direction, and these developments have aroused new interest in the possibility of using peat as an auxiliary fuel.

Already preliminary experiments have been made by the technologic branch of the United States Geological Survey with a large gas producer, which confirm the reports of foreign success in this direction, showing that some peats of American origin are little inferior to many grades of bituminous coal now on the market, and superior to some in the quantity of producer gas to be derived from them and in the calorific value of the gas.

Still more recent than this work is the report from Germany that by the investigations of Doctors Frank and Caro it is possible to recover a large part of the combined nitrogen contained in peat, while it is being converted to gas in the gas producer, as ammonium sulphate; and that where the nitrogen is present in amounts slightly above 1 per cent of the dry matter of the peat, the quantity of ammonium sulphate obtained pays the expenses of maintaining the plant, of gasifying the peat, and a profit besides, leaving the gas as an additional profit. As many American peats have more than 2 per cent of combined nitrogen and a considerable number of analyses show above 3 per cent, it is probable that in the near future peat beds will be profitably utilized for the production of power and ammonium salts in the United States.

This is the more likely when it is considered that the region of most abundant occurrence of peat in large deposits lies along the northern border of the country and in the eastern Coastal Plain. There are also smaller areas where it is found, as in the western mountains and in the moister portions of the Pacific slope. The States containing the greatest amount of peat are the eastern Dakotas, Minnesota, Wisconsin, Michigan, northern Iowa, Illinois, Indiana and Ohio, New York, the New England States, New Jersey, the coastal portions of Virginia, North and South Carolina, Georgia, and practically all of Florida. It is also assumed that there are workable peat beds in the swampy parts of the Gulf States and in those portions of the flood plain of the Mississippi remote from the stream.

It will be noted that these regions of frequent occurrence of peat are practically all outside of the coal fields, with the exception of Michigan, where, as is well known, the coal basin has not been found to be productive except in limited marginal areas, very small in comparison with that of the entire basin.

As a sign of the times it may be stated that work is about to begin in Florida on a plant for generating electric power by producer-gas engines using air-dried peat as fuel, the power to be transmitted to Jacksonville. Aside from other phases of the question it should be remembered that peat can be mined and prepared for the gas producer by the simplest and most inexpensive equipment, and with a minimum of danger, since all of the workings are open cuts made by the use of spades, or of ordinary excavating or dredging machinery, so that none of the dangers of underground mining are encountered.

On the other hand, the great drawback in the preparation of peat for fuel or other uses has always been and continues to be the fact that it contains from 85 to 90 per cent or more of water as it comes from the beds, and that the greater part of this water can not be pressed out but must be removed by evaporation. Peat which is air dry contains from 15 to 25 per cent of water, and its theoretical efficiency is lowered thereby in nearly direct proportion to the amount of water present.

In gas producers of recent types, however, it is reported that peat with 40 per cent water has been used with success, and for this purpose the question of excess of water has apparently been solved by plowing or digging up the peat and allowing it to dry out by exposure to the wind and sun on the surface from which it is taken. In Florida, even in midwinter, peat taken from below the water level, ground in a pug mill, and afterward spread over a drying ground in a layer 8 inches thick, dries to the air-dry state in about three weeks, and is ready for use in a gas producer in less time.

The question of artificially drying peat for fuel has received and is now engaging the attention of able engineers and inventors, and, in the opinion of many, the successful solution of this problem is necessary before any considerable increase in the use of peat for ordinary fuel can be expected.

Briefly stated, the matter rests upon the finding of a way to handle peat with about 90 per cent of water rapidly and cheaply enough so that the 250 pounds of salable material, which will result when it has reached the air-dry state, will pay the cost not only of the processes of preparation, but also of management, amortization, and selling, and return a profit on the original investment. Attention should be called to the fact that if peat with 90 per cent water has its moisture content reduced to 40 per cent, it loses more than half of its content of water, and that this amount is readily extracted by very simple and inexpensive processes.

In Europe, peat is prepared for fuel in several ways designed primarily to render it transportable and efficient as a source of energy. As cut peat it is used extensively for domestic purposes in the form of air-dried sods or blocks cut by hand with specially designed spades. A more compact and efficient fuel is made by more or less thoroughly macerating the peat and pressing it into molds, after which it is dried by spreading the blocks on the ground, exposed to sun or wind, or by grinding it in a specially constructed pug mill similar to that used in grinding clay for making bricks. The peat is ground wet as it comes from the beds, and delivered from the mill in the form of wet bricks, which on exposure to the air and sun's heat for some time become dry, firm, tough, and nonabsorbent. This is machine peat, which is rated the most generally successful form of peat fuel for domestic and boiler use on the markets of Europe. As marketed, this product contains from 20 to 25 per cent of moisture and has, theoretically, about 65 per cent of the fuel value of the same weight of good bituminous coal when burned in stoves or under boilers, but practically, because of the lack of waste of the peat, in the form of ash, smoke, clinker, and unconsumed portions, its real value is higher than is indicated by comparison of the possible heat units to be obtained.

As peat briquets the material is more compact, burns more slowly and persistently, and stands transportation and handling well. The peat is dried thoroughly, powdered, and briquetted, either without or with a binder or in mixture with coal or lignite.

An increasing amount of peat is manufactured into charcoal or peat coke, especially in Germany, where it is used somewhat extensively as a substitute for wood charcoal in smelting iron and in other metallurgical processes, including the refining of copper, steel making, etc. Of the processes so far developed for the manufacture of peat coke none have proved profitable on a commercial scale, except such as condense the distillates and recover a series of by-products similar to those obtained by the destructive distillation of wood, viz, fuel gases, methyl alcohol, acetic acid, lime acetate, ammonium salts, tar and its derivatives. This process involves large preliminary investment and the maintenance of costly plants, but where a good market can be found for the by-products this seems to be justified, according to unbiased and trustworthy reports from Europe. In preparation for coking, the peat is treated exactly as if it were to be sold as machine-pressed peat and is stored in open sheds until needed for the coking retorts.

An increasing amount of peat in the form of powder burned with blast burners is used abroad for firing under boilers and in brick and cement burning; where properly prepared and the firing rightly controlled it approaches theoretical efficiency when used in this way.

The production of gas from peat, as has been stated, has passed beyond the experimental stage, and peat gas is used for mettalurgical purposes, boiler firing, making lime and brick, and to some extent in making glass, while a rapidly growing number of producer-gas plants for using peat are being installed for generating electric power for transmission directly from the larger peat deposits to centers of use.

In view of all of these considerations the following estimates of the peat resources of the United States have been prepared with the view of at least directing attention to the very considerable source of wealth to the nation which is now lying entirely undeveloped in the swamps and bogs of the country. It will also be noted in considering the possibilities of the peat deposits that they furnish potential substitutes for wood in various departments of industry, and in some considerable degree in these directions may relieve the drain upon the vanishing forests.

In making the estimates given below it has been the aim of the writer to be conservative in every detail, and it is believed that in no case will they be found too optimistic.

The total swamp area of the United States, exclusive of Alaska, is estimated to be 139,855 square miles.[a] Of this 8 per cent is assumed to have peat beds of good quality, or 11,188 square miles. The peat in this area is assumed to average at least 9 feet in depth and to contain 200 tons of dry fuel per acre for each foot in depth, or a total of 12,888,500,000 tons. Its value, if converted into machine peat bricks at $3 per ton, would be $38,665,700,000. The value if coked and the by-products of distillation saved would be as follows:

Quantity and value of peat coke and by-products from peat deposits of the United States.

	Product in tons.	Value.
Peat coke	3,608,800,000	[a]$26,005,300,000
Illuminating oils	257,800,000	4,474,200,000
Lubricating oils	90,200,000	
Paraffin wax	38,700,000	3,479,900,000
Phenol	167,500,000	66,345,100,000
Asphalt	25,800,000	824,900,000
Wood alcohol	43,800,000	7,844,000,000
Acetic acid	56,700,000	2,268,800,000
Ammonium sulphate	39,900,000	2,777,400,000
Combustible gases	738,400,000	6,501,300,000

[a] Charcoal price. At coke price the value would be $9,924,200,000.

The better grades of peat coke are nearly free from sulphur and phosphorus, and may be used wherever hard-wood charcoal is required. The quantity of wood required to make charcoal equivalent to the amount of the peat coke given in the estimate would be approximately 8,019,800,000 cords. The uncondensable gas given off from the retorts while the peat is being converted to coke has good fuel value, the maximum being about 300 B. t. u. per cubic foot, and has been successfully used for heating the retorts and for other fuel purposes.

If converted into producer gas by the most recently developed processes, so that the combined nitrogen of the peat is converted into ammonia and fixed as ammonium sulphate, there would be possibly available 619,257,511,000,000 cubic feet of producer gas, with a calorific value of 145 B. t. u. per cubic foot. Assuming 1.5 per cent of nitrogen as an average content of the peat, which is low, since many analyses show more than 3 per cent, 100 pounds of ammonium sulphate to the ton of peat treated in the gas producer could be obtained.

[a] Sixtieth Congress, first session, S. Doc. 151.

On this assumption there is stored up nitrogen enough in the peat to supply at least 644,400,000 tons of ammonium sulphate, having a value of $36,732,400,000, in addition to the gas produced.

Recent tests reported from Europe show that from 2 to 2.5 pounds of peat will produce an effective horsepower per hour, if reduced to gas in a properly designed gas producer and used in the gas engine. Taking the larger amount, to be conservative, it is evident that there is stored up in the peat beds of the country, as estimated above, energy sufficient to develop 10,310,860,800,000 effective horsepower hours.

In Europe great quantities of the more fibrous types of peat are manufactured into stable litter, for bedding live stock, and peat mull, or powder, for absorbent and sanitary uses. Of this class of material it is estimated that there are at least 2,578,000,000 tons available. This class of material is superior to straw and other substances now generally used for the purpose, and would readily bring $10 per ton, or the whole amount has a prospective value of $25,780,000,000. The only factory (located in Indiana) now making a product of this class in the United States sells its entire output of several hundred tons per annum at about $12 per ton.

A single plant for making paper from peat is in operation in Michigan. Possibly 5 per cent of the total amount of the peat of the country is suitable for this purpose, or 644,400,000 tons. The use of this material would reduce the consumption of wood for the purposes of making coarse papers and pasteboard, by whatever amount it displaced wood pulp in the manufacture of such materials.

In the United States peat is being somewhat extensively manufactured into fertilizer filler, material used in making various grades of artificial fertilizers in which slaughterhouse and other refuse animal matter rich in nitrogen are ingredients or in which hygroscopic mineral compounds are used. Peat in the form of dry powder is especially adapted to this use, since it absorbs water and ammonia readily, is a deodorizer, and to a considerable extent prevents fermentation and decomposition. At the prices now obtained for peat suitable for this purpose in the form of dry powder, and considering one-half of the total amount suitable for the purpose, its value is estimated to be $38,666,000,000, or about the same as the valuation of the whole for ordinary fuel.

Ethyl or "grain" alcohol has been made from the less thoroughly decomposed peats in Denmark and Sweden at a cost estimated at about 47 cents per gallon.

If 10 per cent of the entire body of peat in the country can be used in this way, about 70,900,000 tons of alcohol can be obtained from peat. It must be said in passing that this process is as yet hardly past the experimental phases.

Artificial wood, a fireproof or slow-burning composition of peat and mineral cements, has been made in Germany on a small scale for paving blocks and similar uses, as well as for larger structural purposes, as a substitute for wood or stone in buildings. About 10 per cent of the entire peat deposits of the United States may be suitable for this composition, or 1,288,800,000 tons, the use of which would release an equivalent amount of sawed lumber for other uses or to be held in reserve against future need.

Fibrous peat, properly cleansed of the finer material associated with it, is finding a constantly growing use in Europe as packing material for fragile or perishable articles, and for protecting and insulating water and other pipes subjected to the liability of freezing. The peat best adapted to this use is too light in weight and too loose in texture for fuel manufacture, and may be estimated to occur to the amount of 500,000,000 tons, with a market value of $3,000,000,000, displacing excelsior, hay, straw, paper, and other similar materials which are now used.

Fabrics of various qualities and kinds, mattresses for hospitals, and fiber for surgical and other asceptic dressings and as a substitute for silk in cloth weaving have been made from certain grades of peat, but the market is so well supplied with other products for the same purpose, which are of as good or better quality, that the use of the peat products has never reached any extensive commercial scale and does not seem likely to do so in the near future.

It is clearly apparent, however, that in the peat beds of the United States there lies undeveloped—even entirely untouched—a vast amount of raw material from which may be derived, by intelligent and conservative exploitation, fuel, power, fertilizing material, and the raw materials from which may be made a number of valuable products, all of which will serve to supplement other resources which are now known to be limited in quantity. By utilizing these resources also the wealth of the nation may be possibly increased by the not inconsiderable sums which represent the potential cash value of the peat beds and their products, and an equivalent amount of other material will be rendered free for other purposes.

ABSTRACT OF ESTIMATE OF THE PEAT RESOURCES OF THE UNITED STATES.

Peat, a fuel used in Europe to the amount of 10,000,000 tons per annum, is an almost unknown material in the United States, although possessing properties which make it an excellent domestic fuel and desirable for gas production on a large scale.

As the area of the peat beds in the United States, and the quantity of workable material which they contain, is almost unknown, the estimates submitted are but rough approximations. The following are sources of information used here: (1) Publications and topographic maps of the United States Geological Survey; (2) reports of the state geological surveys of New York, Michigan, Iowa, Indiana, Massachusetts, and New Jersey; (3) cooperative reconnaissance peat surveys undertaken by the United States Geological Survey and the state surveys of Connecticut, Maine, and Wisconsin; (4) personal observation of the writer in various parts of the country.

The total area of swamp land is estimated by the United States Geological Survey[a] to be 139,855 square miles. The writer estimates 8 per cent of this to have peat beds which would average 9 feet deep, or 11,188 square miles, with an average possible production of 200 tons of dry fuel per acre-foot, or a total of 12,888,500,000 tons.

The greater part of this material occurs in that part of the country without productive coal fields, in eastern North and South Dakota,

[a] Sixtieth Congress, first session, S. Doc. 151.

Minnesota, Wisconsin, Michigan, New York, and the New England States, in northern Iowa, Illinois, Indiana, Ohio, in the coastal plain region, in eastern New Jersey, Virginia, North and South Carolina, Georgia, and the whole of Florida. The swamp areas of the Gulf States and of the flood plain of the Mississippi River, as well as those of the Pacific States, also contain workable peat beds, but in none of these is there any considerable overlapping of the peaty areas into workable coal fields.

It is estimated that, in the vicinity of the beds, this quantity of peat would have a value of $3 per ton in the form of air-dry blocks, or a total of $38,665,700,000, and that once established on a commercial basis the entire product would find ready sale as fast as produced. If this peat were all used in by-product gas producers, to this value as fuel may be added the value of 644,400,000 tons of ammonium sulphate, which at present prices would be worth $36,732,400,000.

Peat has been successfully used as a source of producer gas, of a form of charcoal or coke, of various by-products from the coke retorts similar to those obtained from wood distillation, of fuel and illuminating gas, of fertilizer filler, and of paper, litter for stables, and packing materials. In these forms the prospective value of the total peat of the country is much larger than as peat fuel.

IRON ORES OF THE UNITED STATES.

By C. W. Hayes,
United States Geological Survey.

INTRODUCTION.

No previous inventory of the iron-ore supplies of the United States in any detail has ever been published, and the present one must be considered only a first approximation which will be materially modified as new quantitative data are made available by future public and private investigations. The estimates of ore supplies given in this paper are not based upon the judgment of any individual, but so far as possible represent the consensus of opinion of those best qualified to form an opinion. Cordial cooperation in making up the estimates has been given by officers of private corporations and the several state geological surveys and by economic geologists and mining engineers generally. Special acknowledgments are due to Messrs. W. N. Merriam, C. K. Leith, D. H. Newland, H. M. Beuhler, W. S. Bayley, T. L. Watson, R. C. Hills, and J. F. Kemp, who have furnished information which could not have been obtained from any other source.

CHEMICAL CLASSIFICATION.

The commercial ores of iron, on the basis of chemical composition, fall into two main classes, i. e., oxides and carbonates. The latter class is relatively unimportant, furnishing in the United States less than one-twentieth of 1 per cent of the annual production. The oxides are further separated, according to the proportion of oxygen and combined water which they contain, into three classes. The chemical and commercial classification is therefore as follows:

1. *Magnetite.*—Magnetic oxide, Fe_3O_4, including titaniferous magnetite. Theoretical iron content, 72.4 per cent. Generally containing some hematite.

2. *Hematite.*—Anhydrous sesquioxide, Fe_2O_3, including specular and red hematite, red fossil ore, oolitic ore, etc. Theoretical iron content, 70 per cent.

3. *Brown ore.*—Hydrous sesquioxide, $Fe_3O_4nH_2O$, including turgite, limonite, goethite, or a mixture of these minerals, known locally as brown hematite, bog ore, etc. Theoretical iron content, 59.8–66.2 per cent.

4. *Carbonate.*—Siderite, iron carbonate, $FeCO_3$, known locally as spathic ore, black band ore, kidney ore, etc. Theoretical iron content, 48.2 per cent.

GEOLOGIC CLASSIFICATION.

In their geologic relations and mode of occurrence the iron ores may be further classified as follows:

1. *Magmatic segregations in basic igneous rocks.*—The titaniferous magnetites of the Adirondack region represent this type. A characteristic of such deposits is the perfect gradation from the ore into the surrounding rock by an increase in the gangue, which consists of the same minerals as the associated igneous rock. The deposits are of great size and present large possibilities of utilization by concentration or with modification of furnace practice which will permit their economical reduction.

2. *Contact deposits, formed in connection with the intrusion of igneous rocks at their contact with the intruded sediments, generally limestones.*—These appear to be due to ascending heated waters and vapors given off by the cooling igneous rock. The ores include both magnetite and hematite. Typical examples are the Cornwall deposits of Pennsylvania and many of the western iron-ore deposits, as those at Hanover, N. Mex., and Iron Springs, Utah.

3. *Concentration deposits.*—These include all forms of the oxide ores in which the iron, originally disseminated through the rocks, has been dissolved, transferred, and redeposited by circulating waters. It includes most of the brown ores of the Appalachian region in which the iron was originally disseminated through a great mass of limestones and shales and has been leached out and concentrated by surface waters during the erosion of these rocks. In some cases the iron was probably deposited as carbonate or sulphide and subsequently changed in place to hydrous oxide. It includes the bog-ore deposits, which have been formed or are now forming in swamps, to which iron is brought in soluble form as organic compounds and precipitated by the breaking up of those compounds through oxidation.

4. *Replacement deposits.*—These are closely related to the concentration deposits, the principal difference being that the ore-bearing solution has derived the iron from an outside source and deposited it in place of some definite portion of an original rock series, generally a limestone. They include all classes of ores, both oxides and carbonates, their composition depending on the conditions of deposition and the subsequent alterations which they have undergone. An example of this type is the so-called Oriskany ore of Virginia. In this case the iron derived from a great mass of overlying shales has been carried in solution, and where structural conditions were favorable deposited in place of a certain easily soluble bed of limestone for a variable distance from its outcrop.

5. *Bedded deposits.*—These include all deposits in which the ore forms tabular or lenticular bodies which lie parallel to the bedding or foliation of the inclosing rocks. Their origin may be diverse, but their common characteristic is great lateral extent compared with thickness. In many bedded deposits, though not in all of them, the ore is sharply differentiated from the surrounding rocks. Magnetite deposits of this type are the Adirondack ores associated with metamorphic sediments and with gneisses of uncertain origin. Of the hematite deposits of this type are the enormous deposits of the Lake Superior district, where certain beds of the iron formation have been enriched both by the removal of silica in solution and by the depo-

sition of additional iron. It also includes the gray specular ores of Alabama, which are associated with Cambrian and pre-Cambrian slates and sandstones, and the important red ores, fossil and oolitic, which form regular sedimentary beds, differing only in composition from associated Silurian sandstones and shales. Of the carbonates it includes the black-band ores, which occur as layers of nodules or continuous beds associated with the "Coal Measures" in Ohio and Pennsylvania.

6. *Gossan deposits.*—Iron sulphides tend to oxidize with loss of sulphur when exposed to surface weathering, and deposits of pyrite and pyrrhotite are therefore generally covered with a deposit of residual brown ore, which extends down to the level of permanent ground water. Examples of this type are the brown ore on the outcrop of the pyrrhotite veins at Ducktown, Tenn., and the iron-ore capping of many metalliferous veins in the West.

Referred to the ultimate source of the material, it may be stated in general that the iron ores are derived from the iron minerals either segregated or disseminated in igneous rocks or the iron minerals deposited by igneous emanations, which have been worked over in varying degrees by the agents of weathering and sedimentary and chemical deposition at the surface of the earth. Iron compounds are among the most stable substances under surface conditions, and hence the net result of the changes at the earth's surface is to concentrate iron minerals mechanically and chemically as compared with associated minerals.

VALUE OF ESTIMATES.

An understanding of the above chemical and geologic classifications of iron ores is essential for an appreciation of the limitations and uncertainties of any estimate of the ore supplies of the country. It will be readily understood that with the great diversity in type of deposits there must be a very wide difference in the degree of accuracy with which the ore can be estimated. The closest approximation can be made in case of bedded deposits such as the Clinton red hematites. These beds vary in thickness and composition from place to place, but the variations are similar to those characterizing other sedimentary beds such as coal, and with a minimum amount of testing on the outcrop and at depth their contents can be calculated with a fair degree of certainty. Certain assumptions, however, must always be made. Thus it is assumed that observed variations in composition and thickness continue with regularity between and beyond points of observations; also that a certain depth will limit workability. This limiting depth will depend upon a variety of conditions which can not be determined in advance of mining, and hence the depth fixed upon in making calculations will be largely a matter of opinion, and must be expected to change with changing commercial conditions. Hence it is doubtful if even the best known and most thoroughly tested deposits of red hematite can be estimated within 10 per cent of their actual yield. At the other extreme are the concentration deposits of brown ore. These are extremely variable both in depth and horizontal extent. Surface indications are thoroughly unreliable, and those most experienced in working such deposits are practically unanimous in the opinion that no deposit can be safely estimated until every ton of ore has been mined. Under such circumstances the estimates given below of ore remaining in this class of deposits can only be regarded as having a degree of accuracy represented by a factor varying between 0.7 and 3.

Intermediate between these extremes are the most important deposits, including those of the Lake Superior and Adirondack districts. The former by reason of their greater regularity and the thoroughness with which they have been tested may be considered as known within 15 or 20 per cent. The latter are much less fully tested, and estimates of their probable yield are based upon assumptions which further development may prove to be erroneous. Estimates of the western ore deposits vary in value because of inherent uncertainties due to the nature of the deposits and to the very unequal information concerning different districts.

AVAILABILITY.

Any estimate of the iron-ore supplies of the United States must separate the ores into two classes on the basis of availability. This separation is difficult, and opinions vary widely as to where the line should be drawn. Evidently the question is one of costs: (*a*) The cost of the ore delivered at the furnace and (*b*) the cost of reduction. Actual production, past and present, being determined by the interaction of various factors, affords the best criteria of availability.

The two factors which enter most directly into the cost of ore at the furnace are accessibility and mining conditions. Many iron-ore deposits are known in regions so remote from fuel supply and from transportation lines that they may be considered unavailable at present or so long as they are compelled to compete with more accessible ores. At the same time they must be taken into account in considering the total reserves, for accessibility is only relative and no deposit, if sufficiently large to warrant the expenditure necessary for construeting roads, can be regarded as permanently inaccessible. Distance from fuel is, of course, a more serious drawback than absence of present means of transportation, while those supplied with water transportation will bear a longer haul than those carried entirely by rail.

Mining conditions may be such as to make the cost of raising the ore prohibitive at present. Such conditions are limiting depths beyond which mining, on account of the amount of water, may become very expensive, or thinness of the beds which necessitates a large amount of dead work. These conditions apply particularly to the Clinton ores and explain the difference between the total amount proved in these deposits and the amount considered at present available. Many deposits of brown ore can be worked cheaply in open pits for a certain distance from the surface, while the cost of stripping or of timbering to hold back the inclosing clay prevents their working to greater depths.

Another kind of limiting conditions arises from the fact that in many cases the ore is mixed with foreign material from which it must be separated. Thus many of the brown ores consist of small concretions scattered through clay, and a large amount of material must be passed through the washer to obtain the ore in suitable condition for the furnace. The ratio of ore to clay in deposits now being worked varies from 1:5 down to 1:20. When conditions permit the lowering of this ratio still further, large quantities of ore will be available in material which can not now be worked at a profit. Similar conditions control the availability of many of the magnetic deposits, except that here the objectionable elements are other minerals that are closely associated with the iron and must be separated by magnetic methods. The concentrated material is a high-grade ore, and the ratio of available to nonavailable in these deposits depends wholly upon cost of the process of concentration which they will bear in competition with other ores.

The second consideration affecting availability is the character of the ore itself. The content of metallic iron in ores used at present varies from 30 to 65 per cent. This wide variation is due in part to the nature of the other elements in the ore and in part to advantageous location. Thus the Clinton ores, containing as low as 30 per cent iron, can be used with advantage, because the lime which they contain makes them practically self-fluxing. At the same time they must be used near the point of production, since the low content of iron will not permit long transportation in competition with richer ores. On the other hand, siliceous ores containing less than 40 per cent iron are not considered at present available unless their location near the fuel is exceptionally favorable, since the cost of transportation per unit of iron is excessive and since a large amount of fuel is required to remove the silica. But there are enormous quantities of siliceous ore carrying from 35 to 40 per cent iron, particularly in the Lake Superior district, and this must be taken into account as a future reserve, though not at present available.

In the case of the titaniferous magnetites the ratio between the available and not available is difficult to determine. While these ores have been used only to a limited extent because of the difficulties attending the fluxing of the titanium, it seems probable that these difficulties will be overcome and a much larger use made of them either by employing a special flux in the furnace or by reducing the percentage of titanium in the charge by concentration or mixing with nontitaniferous ores.

The percentage of other constituents, such as phosphorus, sulphur, copper, chromium, manganese, and alumina, will determine the method and cost of reduction and the quality of the resulting iron. Hence these constituents, some of which are highly deleterious, may determine the question of availability by limiting the conditions under which the ore can be reduced or the product used.

Another factor is the nature of ownership. Where a large corporation controls a variety of ores and is equipped to assemble them and form any desired mixture or grade, ores may be used with advantage which would not be available if held by a smaller company not in a position to control the situation in a large way or compelled to dispose of a single kind of ore in the open market.

Because of the varying importance of these factors, future availability will obviously vary in a corresponding degree and the advantage which one district now possesses may pass to another. As the higher-grade ores of the Lake Superior region become depleted the lower-grade ores will be called upon with consequent increase in cost of transportation and smelting. The low-grade ores of the southeastern district, at present competing with the high-grade Lake Superior ores, will then have a decided advantage because of proximity to fuel supply.

The notable present tendency in the iron industry is the lower average iron content in the ores used. This tendency will undoubtedly continue in the future as the more easily accessible portions of the richer deposits are worked out. As a corollary to this is the observed tendency toward a decentralization of the iron industry, and with a decrease in the iron content of the ore used, involving a corresponding increase in cost of transportation per unit of iron, there will be an increase in the proportion of fuel which goes to the region producing the ore. This will be accompanied by the general adoption of by-product coking. It is an instructive fact that in certain furnaces now operating in the Lake Superior district the profit corresponds approximately to the value of the by-products from the coke ovens.

In making estimates all of these considerations, together with the best forecast that can be made of conditions as they will exist in the next ten years, have been taken into account in determining the ratio between available and nonavailable supplies.

GEOGRAPHIC AND GEOLOGIC DISTRIBUTION.

Iron being one of the most abundant elements, fourth in order of abundance, its natural compounds are found in practically all rocks and soils. To constitute an ore, however, certain of these minerals must be segregated into deposits of sufficient size and purity to permit economical working. Such deposits, considering the entire area of the country, are relatively infrequent. Iron ore is at present produced in only 29 of the 47 States and Territories, and about 79 per cent of the production (1907) was from two States—Minnesota and Michigan. It is evident that the distribution of the deposits is extremely uneven.

For convenience of description of the ores and discussion of the estimates the known ore deposits will be taken up by groups based on distribution and kind. A few deposits are not included in any of these groups, but the total tonnage of ore which they contain is so small as to be negligible in an estimate of the total for the entire country. The groups of deposits to be considered are the following: (1) Lake Superior ores; (2) Adirondack ores; (3) Clinton ores; (4) Appalachian metamorphic ores; (5) Appalachian brown ores; (6) Appalachian carbonate ores; (7) West Tennessee brown ores; (8) East Texas brown ores; (9) Ozark ores; (10) Rocky Mountain metamorphic ores; (11) Igneous contact ores.

(1) LAKE SUPERIOR ORES.

[Based on information furnished chiefly by C. K. Leith.]

GEOLOGIC RELATIONS.

The Lake Superior ores, chiefly hematites with subordinate amounts of magnetite, constitute approximately 80 per cent of the annual iron-ore production of the country. The total production from the region from its opening to the close of 1907 has come from the ancient folded and metamorphosed pre-Cambrian formations in Michigan, Minnesota, and Wisconsin in proportions shown in the following table:

Geologic sources of Lake Superior iron ores.

State.	District.	Geologic horizon.		
		Keewatin.	Middle Huronian.	Upper Huronian.
		Per cent.	*Per cent.*	*Per cent.*
Minnesota (46.555 per cent)	Mesabi			39.45
	Vermilion	7.105		
Michigan (50 per cent)	Gogebic			12.24
	Marquette		21.90	.50
	Menominee, including Crystal Falls, Iron River, etc.			15.46
Wisconsin (3.308 per cent)	Penokee			1.98
	Menominee (Florence)			1.26
	Baraboo			.068

The iron formations are sedimentary deposits, usually interbedded with slate, quartzite, dolomite, and sometimes with basic extrusives. They consisted originally of chert, containing beds of iron carbonate or of dark-green ferrous silicate granules, called greenalite. As a result of surface oxidation of the iron carbonate and greenalite, the great bulk of the formation within the zone of observation now consists of chert minutely interbedded with limonite or hematite, giving a banded rock variously called ferruginous chert, taconite, or jasper. The average proportion of iron in these siliceous rocks is between 25 and 37 per cent. Numerous slate layers form subordinate proportions of the iron formation.

The iron ores constitute concentrations of ore in the exposed parts of the iron formation, accomplished mainly by taking out the associated silica and leaving the iron in larger percentage, but also partly by solution, transportation, and redeposition of the iron when it is still in its soluble ferrous condition. The agents of alteration are surface waters carrying oxygen and carbon dioxide. The accessibility to the iron formation of these agents therefore determines the location, shape, and size of the ore deposits. The most favorable condition of accessibility is given by wide area of exposure of the iron formation, which is in turn a function of the dip. The flat-lying formation in the Mesabi Range exposes a greater surface to concentrating agents than the steeply dipping formation of similar thickness and character in the Gogebic range, with the result that the proportion altered to ore is much greater in the Mesabi district. A comparison of the actual areas of the different iron formations with their total shipments to date, and with their probable reserves, shows a very close relation between area and amount of ore developed. Also determining accessibility of the concentrating agents to the iron formation are numerous structural conditions, such as joints or faults or impervious pitching basements, favorable to rapid circulation of water. Finally, the texture of the iron formation itself, whether dense or porous, may determine the activity of the circulation of the waters.

It is therefore apparent that the size, shape, depth, and structural relations of the Lake Superior ores are in widest variety. In the flat-lying formations of the Mesabi Range the ore bodies have wide lateral extent as compared with depth, extremely irregular outlines partly controlled by jointing, abut irregularly on bottom and sides against unaltered portions of the iron formation, and when the glacial overburden is removed, are accessible to surface operations with steam shovels. In steeply dipping beds they have greater vertical as compared with horizontal dimensions, usually abut not only against unaltered parts of the iron formation, but against well-defined impervious walls consisting of slate, quartzite, dolomite, or bosses or dikes of greenstone, and in such beds underground mining is necessary. The maximum depth to which mining has extended is a little over 2,000 feet; the maximum horizontal extent thus far worked in a single mine is less than a mile, but deposits are known to connect for nearly 10 miles. An adequate summary of the variety of structural features of the several districts can not be made within the limits of this paper.

CHARACTER OF THE ORES.

The hematites and limonites making up the great bulk of the Lake Superior ores range in texture from soft and powdery to hard and crystalline. Both kinds usually have large pore space, due to the removal of silica by leaching. Locally, however, where the ores have been buried deeply in the zone of rock flowage, they have become dense, schistose, specular hematites and magnetites lacking pore space. Where the iron formation has been intruded by large masses of igneous rocks the ores are magnetic. The ores range in grade from above 60 per cent in iron down to 25 per cent in the lean parts of the iron formation. The average shipment for 1906 for the entire region was 59.8 per cent in iron. The difference between the iron ore and the iron formation is simply in the proportion of silica present.

The ores mined in the Lake Superior region to date have generally run above 50 per cent in iron. The lowest grade shipped has been about 40 per cent, in the case of local ores in demand for mixtures and favored by cheap mining and transportation. In mining much material running 40 per cent or even less is taken out and mixed with higher-grade ores to give a medium grade. Such low-grade material therefore does not figure obviously in the production. The percentage of iron in the ore mined from the region has fallen slowly but steadily in recent years, but the major part of the shipment is likely to remain above 50 per cent for some years to some. In the present estimate of available ores about 50 per cent of metallic iron has been taken as the minimum. It is fully appreciated that ores below this grade are even now locally available and will soon be used in larger quantities, but such ores as a whole must be considered still as belonging to the future supply. The ore supply of the Lake Superior district available under present conditions is therefore taken to include all ore above 55 per cent iron, estimated at 2,500,000,000 tons, and 25 per cent of all ore containing between 45 and 55 per cent iron, giving a total of 3,500,000,000 tons exclusive of the Clinton ores.

ESTIMATES OF LOW-GRADE ORES.

Difficulties beset estimates of the tonnage of low-grade ores available for the future. The lower limit of such grade must be chosen somewhat arbitrarily, and when it is chosen there is lack of sufficient analyses of the iron formation as a whole to separate the tonnage above the given grade. The mixing of high-grade and low-grade ores also complicates the situation. Extensive drilling operations have been directed mainly to determine the percentage of ore above 50 per cent and little attention has been given to the grading of ores running below this percentage. The averages of all available analyses from portions of the formation outside of the ore at present available, made by the mining companies of the Lake Superior district, give the following results:

Character of the iron-bearing formations of the Lake Superior district.

DIAMOND-DRILL CORES.

State.	Holes.	Average iron content.	Analyses.	Total footage.
		Per cent.		
Michigan	77	36.52	3,897	22,202
Minnesota	24	38.00	1,094	5,400
Wisconsin	30	36.40	1,517	4,814

OTHER SOURCES.

Michigan:				
Trenches	....	41.53	94	975
Levels	....	38.40	905	[a] 7,500

[a] Approximate.

It seems entirely probable, in view of the fact that 40 per cent ore is even now locally in demand, that the depletion of the higher-grade reserves may in time require the use of 35 per cent ore. If so, the tonnage is enormous. Planimeter measurements of areas of the iron formation, multiplied by the depths quite within the limits of actual mining at the present time, give the following results:

Tonnage of iron formations.

District.	Area.	Depth.	Volume.	Quantity.
Michigan:	*Sq. miles.*	*Feet.*	*Cu miles.*	*Tons.*
Crystal Falls	7.80	1,250	1.950	19,500,000,000
Marquette	28.50	1,250	7.100	71,000,000,000
Menominee	5.60	1,250	1.400	14,000,000,000
Penokee	11.60	1,250	2,900	29,000,000,000
Swanzy	1.00	1,000	.200	2,000,000,000
Minnesota:				
Mesabi	127.00	400	10.000	100,000,000,000
Vermilion	15.60	1,250	3.900	39,000,000,000
Wisconsin:				
Florence	.70	1,250	.175	1,750,000,000
	197.80	....	27.625	276,250,000,000
Ontario, Canada:				
Animikie	10.80	100	.20	2,000,000,000
Michipicoten	6.64	1,250	1.66	16,600,000,000
Other districts on north shore of Lake Superior	30.00	1,250	7.50	75,000,000,000
	47.44	....	9.36	93,600,000,000
Total	245.24	....	36.985	369,850,000,000

It is not proved, however, that this enormous tonnage will average as high in iron as these figures from the mining companies would indicate. Indeed, many parts of the formations are known to run lower than this. It is regarded safer, therefore, to use a smaller figure for the tonnage of ore running 35 per cent and over. Just what fraction of the total tonnage of the iron formations should be taken is a matter of more or less arbitrary choice. It is here put at 72,000,000,000 tons, divided as shown in the following table:

Estimates of Lake Superior ores.

District.	Available.	Not available.
Michigan:	*Long tons.*	*Long tons.*
Marquette district	110,000,000	15,900,000,000
Gogebic district	95,000,000	3,900,000,000
Menominee, Crystal Falls, and other districts	80,000,000	7,360,000,000
Minnesota:		
Mesabi district	3,100,000,000	39,000,000,000
Vermilion district	60,000,000	1,005,000,000
Cayuna and other districts	15,000,000	310,000,000
Wisconsin	40,000,000	4,525,000,000
Total	3,500,000,000	72,000,000,000

(2) ADIRONDACK ORES.

[Based on reports of the New York State Survey.]

The area of crystalline rocks forming the Adirondack district occupies the greater part of the State of New York north of the Mohawk Valley. The district contains a variety of iron ores differing in their character and geologic surroundings. Those found in sufficient abundance to be commercially important are nontitaniferous magnetites, titaniferous magnetites, and red hematites. Some deposits of limonite also occur as bog ores, but they are not generally of sufficient size to be considered an available source of ore at the present time.

The rocks of the Adirondack district, with the exception of small patches of Paleozoic sediments, are entirely pre-Cambrian, and are either wholly crystalline or highly metamorphosed. They are provisionally classed in three groups: (1) Sedimentary rocks, marble, schist, and gneiss; (2) gneisses of undetermined origin, but probably in part, at least, sedimentary; and (3) igneous plutonic rocks, anorthosite, gabbro, syenite, and granite. The first group occupies a relatively small part of the area, but with its various members are associated all of the hematite deposits and many of the nontitaniferous magnetites.

NONTITANIFEROUS MAGNETITES.

These are the most widespread of the Adirondack deposits, but the more important ones occur in two groups on the eastern border of the district in the Lake Champlain basin and in the western part of the district in St. Lawrence County. In the first group are the well-known Hammondville, Mineville, and Lyon Mountain deposits, and in the second the Benson, Jayville, Fine, and Clinton deposits.

The ores show great variation in their mineral and chemical composition, ranging from lean varieties, which consist of magnetite intermixed with the constituents of the wall rock, to those made up of practically pure magnetite. The richest, obtained principally from the Mineville group, average from 60 to 65 per cent iron, and considerable quantities have been obtained which approached the theoretical iron content of magnetite (72.4 per cent). The deposits carrying less than 50 per cent iron are generally considered too refractory for direct smelting and their utilization depends upon concentration. Large bodies of such ore occur in the Lyon Mountain, Arnold Hill, and St. Lawrence County deposits. The lowest grade of ore now worked carries about 35 per cent iron ore before concentration.

Both Bessemer and non-Bessemer ores occur, in some cases in adjoining deposits, though generally the ores from all deposits of a group show a fair degree of uniformity in respect to phosphorus content. The leaner ores are apt to be lowest in phosphorus, and concentrates produced at Lyon Mountain contain less than 0.01 per cent of that element with 65 per cent iron. The ores also carry a variable proportion of sulphur due to the admixture of pyrite and more rarely pyrrhotite.

The deposits occur in a variety of forms such as are common to the magnetites found in gneisses and schists elsewhere. In general they have a lenticular bedded form and are parallel to the foliation of the inclosing rocks. They partake of the same structural folds and faults as these rocks, and must therefore have been deposited before the regional compression occurred to which these structural features are due. While there has been much diversity of opinion regarding the origin of these ores, the view generally held at present is that they were introduced by processes connected with the intrusion of the igneous rocks.

The Adirondack magnetites were mined as early as the latter part of the eighteenth century and supplied many bloomeries and forges and, later, small charcoal furnaces. These have now all disappeared, and the ores are mostly shipped to the iron-making centers for smelting. There are, however, two coke furnaces in the region that are supplied by local mines. The total production up to the present time has been somewhat over 36,000,000 tons. Both open-cut and underground mining methods are employed, but chiefly the latter because of the high inclination of the ore bodies. A depth of 1,500 feet has been reached in the workings at Lyon Mountain, and about 2,000 feet at Barton Hill. Practically all of the ore is concentrated by the magnetic process, which yields concentrates containing from 60 to 65 per cent iron and at the same time effects a partial elimination of the phosphorus and sulphur. In fact, the treatment of the richer ores is designed primarily to reduce the phosphorus, and the concentration is a subordinate object.

While a few of these deposits have been drilled with sufficient thoroughness to permit a fairly definite estimate of their contents, this is not generally the case, and in most cases even the extent of the outcrop is not accurately known. Lines of magnetic attraction indicate the presence of ore bodies concerning which little else is known, and finally large areas in the Adirondack Mountains, heavily forested and drift covered, have not been examined in sufficient detail to determine whether or not they contain iron-ore deposits.

For these reasons it is impossible accurately to determine the ore reserves. It is estimated that the known deposits of high-grade ore will yield 35,000,000 tons, and that the leaner deposits, carrying over 35 per cent iron, will yield 75,000,000 tons of concentrates. The estimate of ore which is not now available because of great depth, or low grade, but which may be used eventually, is even more uncertain, but may be placed conservatively at 25,000,000 tons.

TITANIFEROUS MAGNETITES.

Under this class are included the ores which carry titanium as an essential ingredient. In general it amounts to at least 8 per cent of titanic acid (TiO_2), while the average is perhaps 15 per cent. These deposits occur within the margins of the gabbro-anorthosite area, chiefly in Essex and Franklin counties. In their relations to the inclosing rocks these deposits are sharply differentiated from the nontitaniferous magnetites which occur in the sedimentary and eruptive gneisses and schists. The titaniferous ores are believed to be the product of magmatic segregation, and hence intimately connected in origin with associated igneous rocks. The form of the ore bodies has not been accurately determined except in the case of a few of the smaller ones. The large bodies have nowhere been uncovered or sufficiently explored to afford an idea of their precise outlines. The richest ores contain little else than magnetite and ilmenite, and yield fully 60 per cent iron. From such pure aggregates there may be traced a continuous series of gradations by the entering of gangue minerals in increasingly greater proportion to the limiting wall rocks which hold only subordinate amounts of magnetite and ilmenite. The two minerals are often distinct in their crystallization, and show no tendency toward mutual intergrowth.

The use of ores containing high percentages of titanium is generally regarded as impracticable under present furnace practice because of the infusibility of the slags. They have, however, been smelted on a small scale in the Adirondacks, as well as in England and Sweden, and experiments have shown the feasibility of securing a fusible slag by properly proportioning the fluxes. A more promising solution of the problem is found in a reduction of the amount of titanium entering the furnace, both by concentration and by employing these ores as mixtures with nontitaniferous ores. Since the ilmenite is only feebly magnetic, it has been found practicable, at least on an experimental scale, to reduce the titanic oxide from 15 to 8 or 9 per cent by moderately fine crushing and magnetic concentration.

These deposits have been explored only far enough to prove that they contain a very large amount of ore which simply awaits the development of methods for overcoming the metallurgical difficulties due to the presence of the titanium. Assuming that these difficulties will be overcome, it is estimated that the known deposits in the Lake Sanford district alone contain at least 90,000,000 tons sufficiently accessible and high in grade to be now available, and that they may contain in addition 100,000,000 tons, which are not now but will be eventually available as an ore supply.

RED HEMATITES.

Hematite deposits of workable dimensions occur on the northwestern side of the Adirondacks in Jefferson and St. Lawrence counties. They are associated with the folded pre-Cambrian sedimentary (Grenville) series of schists, limestones, and gneisses, which attain greater areal development in that section than elsewhere in the Adirondack region. The ores are mainly soft, red hematites, with subordinate specular, and occupy zones of replacement along the contact of crystalline limestone and schist, and at times in the schist itself, with often a capping of Potsdam sandstone. A peculiar feature is the presence of a greenish mineral—locally called serpentine, but of chloritic nature—which seems to be an alteration product formed by reaction of the iron-bearing solutions upon the feldspathic schists and the occasional granitic intrusions of the walls. The source of the iron may be traced with some certainty to bands of pyrite and magnetite, which abound in the schists and which are subject to rapid weathering and to solution by ground waters. The principal mines have been opened along a narrow belt extending northeast from Antwerp nearly to the village of Gouverneur, but there are a number of outlying deposits that have been worked in former days for the supply of local furnaces. Mining was begun about 1835. Altogether the district has furnished probably 2,500,000 tons of non-Bessemer ore ranging from 45 to 60 per cent iron. The largest mines are the Dickson and Old Sterling near Antwerp and the Caledonia and Spragueville. Of recent years the output has been shipped to New Jersey and Pennsylvania for reduction.

Aside from the actual mine workings the district is practically unexplored, and it is impossible to draw any accurate conclusions as to the quantity of ore that may exist. Judging from the ore bodies developed in the mines recently operative, it seems safe, however, to place the resources at present available at 2,000,000 tons, while an equal quantity may be represented by other deposits that are not now workable by reason of their inaccessibility or other unfavorable circumstances.

Estimates of Adirondack ores.

	Available.	Not available.
	Long tons.	*Long tons.*
Nontitaniferous magnetites:		
High-grade ores	35,000,000	....
Concentrating ores (concentrates)	75,000,000	25,000,000
Titaniferous magnetites	90,000,000	100,000,000
Red hematites	2,000,000	2,000,000

(3) CLINTON ORES.

CHARACTER OF THE ORE.

The Clinton iron ore, so named from its typical occurrence at Clinton, N. Y., is an amorphous red hematite mixed with calcium carbonate, silica, aluminum silicate, and other minerals in minor quantities. It includes the varieties known as fossil ore and oolitic ore.

It occurs in lenticular beds analogous to the strata of sandstone, shale, and limestone, with which they are interbedded.

The fossil ore consists of aggregates of fossil organic remains in which the original calcium carbonate has been replaced partly or wholly by ferric oxide. The fossils, which consist of broken and waterworn fragments, were evidently gathered into beds by the action of waves and currents, and subsequently cemented together by calcium carbonate and ferric oxide. More or less clay material was also included in the beds during their deposition, and this now forms thin seams of shale.

The oolitic ore consists of aggregates of flat grains with rounded edges about the size and shape of flaxseeds. These grains generally lie parallel to the bedding planes of the rock, and the mass is cemented by ferric oxide and more or less calcium carbonate. The flattened grains have a nucleus of quartz, generally very minute, about which successive layers of iron oxide, and, in many instances, thin layers of amorphous silica and aluminous material, have been deposited. One of the two varieties of ore generally predominates in a bed, but in certain localities both fossil and oolitic materials are mixed in nearly equal proportions. The fossil ore, where unweathered, as compared with the oolitic ore in the same condition, is apt to be the more calcareous, while the oolitic ore may carry higher proportions of silica and alumina.

A characteristic of the Clinton ore is that where it has been weathered or acted upon by surface waters the lime carbonate is dissolved out, thereby increasing the content of iron oxide, silica, and other constituents proportionately. Such altered ore is termed "soft ore," and it is usually porous and friable as compared with the unaltered material, which is termed "hard ore." The alteration of the ore beds takes place at the outcrop and extends to varying depths from a few inches to 400 feet, depending on the attitude of the beds and on the thickness and permeability of the overlying rocks. The quantity of the soft ore is relatively small in comparison with the hard ore, and owing to its higher content of iron and its greater accessibility, a large part of the soft ore has already been mined.

In general the hard and semihard ores range in percentages of major constituents as follows: Metallic iron, 30 to 45 per cent; lime, 5 to 20 per cent; silica, 2 to 25 per cent; alumina, 2 to 5 per cent; magnesia, 1 to 3 per cent; phosphorus, 0.25 to 1.5 per cent; sulphur, a trace to 0.5 per cent; and water, 0.5 to 3 per cent. The ore is therefore of non-Bessemer grade. Small quantities of manganese are found in the Clinton ore in places, especially in the South. The content of this mineral seldom exceeds 0.25 per cent. In the soft ore the lime generally runs less than 1 per cent, so that the percentages of the other constituents are proportionately higher.

GEOLOGIC RELATIONS AND DISTRIBUTION.

The Clinton formation, of which the Clinton ore beds are a part, consists of lenticular, overlapping sedimentary beds, chiefly shale, sandstone, and limestone. In some places shale predominates, in others sandstone, and less commonly limestone. One or more iron-ore beds are generally present, although over considerable areas none occur.

The formation has a wide distribution in the eastern half of the United States. In the Mississippi Valley it is present in Wisconsin and Missouri, in the latter State having been recognized in a drill hole by the presence of a bed of iron ore over 8 feet thick at a depth of 2,000 feet. In eastern Wisconsin the formation is represented by a bed of iron ore only, which varies in thickness from 1.5 to 25 feet. In Ohio, Indiana, and northeastern Kentucky the formation occurs generally with thicknesses of 35 to 50 feet, but containing ore only in the latter State. In northern New York the Clinton rocks extend in a east-west strip from Niagara River to Otsego County. Here the thickness ranges from 32 to 295 feet. In all these States the beds are approximately horizontal or dip at very low angles. In the Appalachian belt from northern Pennsylvania southwestward to central Alabama the Clinton is a well-developed formation, and the beds are generally inclined at angles varying from 10° to 90°. The thickness of the formation decreases from 2,000 feet in Pennsylvania to about 850 feet in Virginia, 300 to 750 feet in Tennessee, and 200 to 700 feet in Alabama and Georgia.

While the total length of outcrop of all the areas of ore-bearing Clinton formation would reach several thousand miles, only a relatively small part of this outcrop contains ore workable under present conditions. The workability of an ore bed depends on its thickness, extent, composition, and attitude, and also upon its situation with respect to transportation routes, fuel, and markets. The first set of factors are of greatest importance, since few areas of good ore are so inaccessible that they will not sooner or later be reached by railroad. Local conditions also play an important part in determining the workability of an ore bed. For instance, in districts where several such beds occur in the formation, as in Alabama, only the thicker and richer ores are now worked, while others that would be at once exploited if they were in Pennsylvania are for the present neglected.

Wisconsin.—In Wisconsin Clinton ore has been produced in Dodge County since 1849. The ore occurs at Iron Ridge in an irregular lens-shaped bed between the "Cincinnati shale" and the Niagaran limestone. Its thickness varies from 1.5 to 25 feet. At other points, within a radius of 10 miles, the same ore bed occurs and it is known to thin out to the east. Toward the west the ore has been eroded, so that the outcrop lies in a westward-facing scarp about 60 feet high, capped by Niagaran limestone. Open-cut and underground mining have been carried on here. The ore as originally mined ran low in lime and contained about 45 per cent iron. It was partially hydrated and represented the "soft ore" of the outcrop. In 1906 the production of ore from Iron Ridge was nearly 90,000 tons, and in 1907 about 22,000 tons. Recent exploration work has proved that a considerable reserve of hard ore remains in this district, amounting to about 40,000,000 tons.

Kentucky.—A bed of Clinton ore, averaging probably more than 2 feet in thickness, occurs in Bath County, Ky., underlying an area of about 8 square miles. This ore lies nearly horizontal, but most of it is below too heavy cover to admit of mining under present conditions. It carries from 30 to 40 per cent iron and 13 to 16 per cent lime carbonate. At present the ore is mined by stripping where the cover is not more than 8 to 10 feet thick. The deposit has produced approximately 190,000 tons, and it is estimated that there are remaining 25,000,000 tons, one-tenth of which may be available under present conditions.

New York.—The belt of ore-bearing Clinton within New York State extends from Rochester on the west nearly to Utica on the east, a distance of about 130 miles. The width of outcrop of the formation reaches a maximum of 5 miles. The beds dip toward the south, from

45 to 80 feet to the mile. Conditions are extremely favorable for underground mining and should permit work to a distance of 3 to 5 miles from the outcrop wherever the ore is of sufficient thickness. The ore bed that is worked varies in thickness from 1.5 to 4 feet, with an average of about 2.5 feet. It carries 35 to 45 per cent of iron, with an average, where worked, of about 40 per cent. The phosphorus is high, from 0.25 to more than 1 per cent, and the sulphur, while variable, runs from traces up to 0.5 per cent. The ore has been worked in Wayne, Cayuga, and Oneida counties.

An estimate made by the New York State Survey of the tonnage contained in this district, mainly in these three counties, gives a total of 600,000,000 tons. Ore beds less than 1.5 feet thick and at a depth of more than 500 feet, as well as those carrying less than the average content of iron, have been excluded from consideration. Much of this ore, however, is not available under present conditions.

Pennsylvania.—The length of outcrop of the Clinton formation in Pennsylvania is very great owing to its repetition in the many anticlinal folds within the central part of the State. In the counties of Snyder, Mifflin, Juniata, Blair, Huntingdon, and Bedford, three or four thin beds of red ore occur, ranging in thickness from a few inches to more than 2 feet. The ore on the outcrop is usually soft and rich enough to work by stripping, but the hard ore under cover is in most places too thin to be worked at present. In a few places, however, where the beds are from 1 to 2 feet thick, underground drifts and slopes have been driven for short distances in the hard ore. The soft ore carries 40 to 50 per cent of iron and from a trace to 5 or 6 per cent of lime. The hard ore carries 20 to 35 per cent of iron, and in places as much as 25 per cent of lime.

Less than 20,000 tons a year of Clinton ore are now being produced in Pennsylvania, and it is probable that the reserves of this ore at present available in the State are not much in excess of 5,000,000 tons.

Virginia and north Tennessee.—The ore beds in the Clinton in Virginia are generally too thin to be considered important reserves after the soft ore shall have been mined out. In the west-central part of the State beds at Lowmoor range in thickness from 16 to 21 inches, and at Iron Gate from 8 to 12 inches. The soft ore carries 46 to 57 per cent of iron. Nearly 90,000 tons were shipped in 1907 from mines in this district, and at this rate of production most of the easily accessible soft ore will probably be exhausted within ten or twelve years.

The Clinton formation, outcropping along the foot of Cumberland Mountain, is ore-bearing from Cumberland Gap, Va., to La Follette, Tenn. Near Cumberland Gap there are three ore beds ranging in thickness from 6 inches to 2.5 feet. Only the upper bed, the thickness of which ranges from 15 to 20 inches, is workable. Southwestward toward La Follette the ore increases in thickness to 3.5 feet. Here practically all the soft ore has been mined out, so that only a hard ore, carrying 26 to 32 per cent of iron, remains. It is estimated that about 16,000,000 tons of such ore are still available in the Cumberland Gap-La Follette district.

It is possible that future exploration of the extensive areas of Clinton formation within Virginia and West Virginia may reveal additional ore reserves.

Rockwood-Chattanooga-Gadsden district.—This district embraces an area about 30 by 125 miles in the Appalaehian valley region of east Tennessee, northwest Georgia, and northeast Alabama. Steeply dipping Clinton strata outcrop in narrow strips on both sides of Walden Ridge and Lookout Mountain and in the Whiteoak Ridge and other synclines of the Tennessee Valley. Ore is mined at North Chattanooga, Roekwood, Cardiff, Euehee, Welker, and Ooltewah, Tenn., and has been mined extensively at Inman. The important mining localities in Georgia are at Rising Fawn and Estelle, and in Alabama at Battelle, Portersville, Crudup, Attalla, and Gadsden.

The workable ore beds range from 2 to 5 feet in thickness and earry from 30 to 40 per eent of iron, 10 to 25 per eent of lime, and 0.5 to 0.7 per eent phosphorus. The use of much of the ore that is low in iron and high in lime depends upon the eontinuance of supplies of brown ore. The latter is mixed in the blast furnace with red ore that contains more than sufficient lime to be self-fluxing.

Estimates based upon fairly complete examinations place the available Clinton ore of the Rockwood-Chattanooga-Gadsden district at 86,570,000 tons, and the ore that will ultimately become available at 440,000,000 tons.

Birmingham district.—The Birmingham district ineludes the Clinton ore-bearing areas of Alabama from Springville southwest beyond Woodstoek. As in Tennessee and Georgia, the Clinton formation in Alabama outerops in narrow strips on the flanks of synclinal mountains. The dips range from 10° or 15° to vertieal. The most important outerop is along the crest of Red Mountain for about 25 miles near Birmingham. Other areas of minor importanee occur along West Red Mountain near Birmingham. The thiekness of the more important ore beds ranges from 2.5 to 12 feet. The ore earries from 30 to 40 per cent of iron, 10 to 25 per cent of lime, 0.3 to 0.6 per cent phosphorus, and from a trace to 0.1 per eent sulphur.

Estimates of tonnage of available ore for the Birmingham Clinton ore field indicate a supply of probably 358,470,000 tons, and of ore not at present available of about 438,000,000 tons.

SUMMARY AND ESTIMATES.

The Clinton formation has a wide distribution in the eentral and eastern portion of the United States, but eontains commereially important ore beds in only a part of its area. The most important deposits are in the Birmingham, Chattanooga, and New York State districts, while less extensive deposits oecur in Virginia, Wiseonsin, Pennsylvania, and Kentueky.

It is evident from the above deseription that the quantity of ore contained in any area of the Clinton formation may be ealeulated with a fair degree of accuraey, provided suffieient data are available as to its dip and as to variations in thiekness and quality of the ore beds. An assumption must be made as to depth-limiting workability under a variety of struetural eonditions, and since this is a matter of opinion it will vary somewhat widely and introduce eorresponding differences in the results. Conditions of blast-furnace praetice locally may define the quality of a workable ore. In plaees where brown ores are available for mixing with Clinton ores, an ore of the latter class can be used as a flux, although it runs so low in iron and so high in lime that alone it would not be acceptable. The estimates of available ores made by various experts do not, however, differ materially. In case of the total ore which is not now available, but which may be mined eventually, the variance in estimates is much greater, since more unknown factors enter into the problem.

The estimates given below are based upon detailed examinations of the more important districts by the United States Geological Survey for the Birmingham and Chattanooga districts, and by the State Survey for the New York district, with a study of all obtainable drill records.

Estimates of Clinton ores.

District.	Available.	Not available.
	Long tons.	*Long tons.*
Birmingham	358,470,000	438,000,000
Chattanooga	86,570,000	440,000,000
New York	30,000,000	570,000,000
Virginia-North Tennessee	16,000,000	50,000,000
Wisconsin	10,000,000	30,000,000
Pennsylvania	5,000,000	50,000,000
Kentucky-West Virginia	2,500,000	42,500,000

(4) APPALACHIAN METAMORPHIC ORES.

This group includes the deposits of magnetite and specular hematite associated with the crystalline and metamorphic rocks of the Piedmont and Appalachian mountain belts, which extend from southern New York to central Alabama. The ore deposits are not uniformly distributed throughout this area, but are confined to certain portions where geologic conditions have been favorable for their accumulation. The most important districts are (1) the highlands of southern New York and northern New Jersey; (2) the James River district, Virginia; (3) the Cranberry district, North Carolina; (4) the Piedmont district, North Carolina; (5) the Yorkville district, South Carolina; (6) the Talladega gray ore district, Alabama. The last-named district is included in this group for convenience, although it differs materially in its geologic relations from the others.

The ore deposits of this group have the form of lenticular beds or elongated pods, which are interlaminated with the gneisses, schists, or crystalline limestones. The individual deposits vary in thickness from a fraction of an inch up to 50 or even 80 feet, but the majority of the workable deposits are from 4 to 15 feet thick and are apt to show rapid variations by pinching and swelling on both the strike and the dip. They vary in composition from practically pure iron ore to a material containing a large proportion of gangue minerals. In general, the larger deposits contain the smaller proportion of iron and can be worked only by the employment of some method of concentration.

The deposits rarely occur singly, but are more often disposed in rather narrow belts separated by wider belts of barren gneiss and schist. Since the ores were undoubtedly derived from a deep-seated source, there is no reason to anticipate a failure in depth, although pinches and swells are to be expected in the course of deep mining, and the cost of mining will necessarily increase with depth.

The gray hematites of the Talladega district and certain hematite deposits of Virginia and Georgia are here included for convenience, though they occur under entirely different geologic conditions from those above described. These hematites have the appearance of regularly bedded deposits, associated with sedimentary rocks which have suffered only slight metamorphism. Whether or not they were deposited at the same time as the inclosing sediments has not been definitely determined. They possess much greater uniformity, both on the dip and along the strike, than the magnetites in the crystalline rocks, and for practical purposes may be regarded as original bedded deposits.

In view of the irregularities in thickness of the magnetite beds, which can not be determined in advance of thorough prospecting, it is impossible to make any accurate calculation of the amount of ore which they contain even when their area at the surface is known, and this is rarely the case. The following estimates, therefore, are only approximate, particularly the amount assigned to the nonavailable class:

Estimates of Appalachian metamorphic ores.

Ores.	Available.	Not available.
	Long tons.	*Long tons.*
Magnetites, including some titaniferous magnetites and some hematite	47,500,000	74,500,000
Specular hematites, including some limonites	8,000,000	53,000,000

(5) APPALACHIAN BROWN ORES.

This group embraces those deposits of brown ores associated with the Appalachian belt of closely folded sedimentary rocks which extends continuously from northern Vermont southwestward to central Alabama. It is bounded on the east by the older crystalline and metamorphic rocks of the Appalachian Mountains, and on the west by the younger "Coal Measures." It is underlain by limestones, dolomites, shales, sandstones, and quartzites, ranging in age from Cambrian to Carboniferous. The beds, originally deposited in approximately horizontal layers, have been folded and faulted so that they now occupy all possible attitudes. This has given rise to conditions favorable to the rapid weathering of the rocks. The steeply dipping sandstones and quartzites form sharp ridges, while the more easily eroded limestones, dolomites, and shales form the intervening valleys, their surfaces being generally covered with a deep mantle of residual materials. These rocks, particularly the shales and some of the limestones, contain small quantities of iron minerals, sulphides, carbonates, and silicates, and in the process of weathering and erosion, by which many thousand feet of strata have been removed, the iron originally contained in these widely disseminated minerals has been concentrated, where conditions were favorable, as the hydrated oxide forming the deposits of brown ore. These deposits, while presenting great diversity in form, fall into three classes, known as mountain ores, valley or limestone ores, and Oriskany ores.

MOUNTAIN ORES.

These deposits are so called because they always occur upon the flanks or at the base of a sandstone, chert, or quartzite ridge, and throughout Virginia, Tennessee, Georgia, and Alabama they are most extensively developed along the extreme eastern margin of the valley belt where the Cambrian quartzite forms a high ridge flanking the crystalline rocks. The quartzite beds dip steeply beneath the overlying shales and limestones, and iron derived from the latter during the process of weathering has been concentrated downward upon this impermeable foot wall. Similar conditions favorable for ore concentration occur elsewhere in the Appalachian belt where the Cambrian quartzite in isolated ridges dips beneath the overlying shales, as at Anniston, Ala., and also at a few points where the lower Carboniferous chert has formed an impermeable foot wall, as at Sugar Valley, Ga. The deposits present great diversity in form, varying from fissure veins and replacement zones in the sandstone and shale, through blanket deposits resting on the quartzite, to irregular pockets scattered through the residual clay. The last are the most abundant and characteristic. Their size can rarely be determined in advance of development, even by systematic prospecting, and estimates of their available tonnage vary between wide limits.

VALLEY OR LIMESTONE ORES.

These are associated with the great limestone and dolomite formations which underlie much of the Appalachian belt. They are also derived from the iron minerals originally disseminated through the rocks and have been concentrated during the process of weathering and erosion. Their location depends on the original abundance of these minerals in the rocks and on favorable conditions for concentration afforded during erosion, in some cases probably by the fracturing of the beds and the consequent free underground circulation of water, and in others by the location of an easily soluble bed of limestone toward which drainage from surrounding areas brought the iron and deposited it as bog ore. They are always embedded in the residual mantle composed of the insoluble portions of the underlying rocks. The deposits vary in form, but generally consist of concretionary masses ranging in size from those containing several tons down to pellets the size of a pea, disseminated through the residual clay.

ORISKANY ORES.

These deposits are more regular in their occurrence, being limited to a definite horizon in the Helderberg limestone immediately beneath the Oriskany sandstone. They are confined to a comparatively small portion of the valley belt, chiefly in southwestern Virginia with a few deposits in Pennsylvania and West Virginia. The iron was originally disseminated in the overlying shales, and wherever these shales occurred in sufficient thickness and the limestone bed occupied a favorable attitude its lime carbonate has been replaced by the iron oxide for a greater or less distance below the surface. The deposits frequently extend continuously for several miles along the outcrop, being made up of a series of lenses which may reach 75 feet in their thickest portions and thin down to a foot or less where adjacent lenses come together. The greatest depth to which the ore has been found is about 600 feet. Where the replacement has been complete and extensive, therefore, it has the form of a bedded deposit and the ore content can be estimated with some certainty. The deposits consist either of fairly solid ore or of irregular masses and seams of ore embedded in clay.

DEVELOPMENT AND ESTIMATES.

The Oriskany deposits are mined both by stripping on the outcrop and by regular underground mining. The mountain and valley ores are nearly always mined in open pits, in the larger operations by steam shovel, and in a few cases by the hydraulic method. Where hand mining is done, a part of the ore is sent direct to the furnace without other treatment than hand picking, but where the steam shovel is used everything is passed through the washer. In most cases sorting tables and jigs are employed in addition to the washer. By these means the associated materials, consisting of clay, chert, and other rock fragments, are removed from the ore. The average iron content of the ore as shipped is about 45 per cent, and the phosphorus is generally above the Bessemer limit. The deposits of this group, being widely disseminated and easily mined in open pits, furnished a large part of the ores used by the small charcoal furnaces in the early development of the iron industry in the United States. With increase in capacity of furnaces a more reliable ore supply has been sought, and many districts which were formerly heavy producers have been temporarily abandoned. The ore is still in demand, however, chiefly for mixture with the calcareous Clinton ores, and its production will doubtless increase in the future beyond any point previously reached.

From the above description of these brown-ore deposits it will be readily understood that extreme difficulty must attend any attempt to estimate their total tonnage. It is unsafe to base an estimate on the number of known occurrences of the ore multiplied by an average content derived from the known yield of certain deposits which have been worked out, for the best deposits are the ones most apt to be exploited first. The estimates given below are based in part on systematic examination and measurement of all known deposits in certain districts and in part on general considerations of distribution and geologic occurrence. The amounts given in the second column of the table, representing ore not now available, are confessedly little better than guesses and future exploration may show them to be much too low. It should be stated further that estimates made by competent experts differ from the figures here given by a factor varying from 0.7 to 3.

Estimates of Appalachian brown ores.

	Available.	Not available.
	Long tons.	*Long tons.*
New England and New York	1,000,000	1,500,000
Pennsylvania, Maryland, and New Jersey	10,000,000	12,000,000
Virginia, West Virginia, and East Tennessee	35,150,000	136,000,000
Alabama, Georgia, and North Carolina	19,250,000	32,000,000

(6) APPALACHIAN CARBONATE ORES.

This group of deposits includes the beds of carbonate ores and their oxidized outcrops which occur in the Carboniferous rocks within a broad belt stretching from western Pennsylvania through Ohio into northeastern Kentucky, and probably extending also into Tennessee and Alabama. The rocks occupying this belt are chiefly sandstones and shales, with occasional thin beds of limestone. The beds are nearly horizontal, and the topography is such that the outcrop of any stratum is extremely sinuous and may have a length many times the shortest distance between two points. This combination of structure and topography has an important bearing on the possible utilization of the iron ore.

The group embraces several varieties of ore locally distinguished as limestone ore, block ore, kidney ore, and black-band ore, each of which is accompanied by a corresponding variety of oxidation product. All of the varieties are non-Bessemer ores. The limestone ores are associated with thin beds of limestone, the most widely distributed being the Vanport and Maxville. The ore beds lie immediately above the limestones, which they sometimes entirely replace. They are usually only a few inches thick, but occasionally expand to several feet. For varying distances from the outcrop the original iron carbonate has been oxidized to a dense brown ore, with loss of carbonic acid and increase in proportion of iron. The unaltered carbonate contains 30 to 35 per cent iron, and the alteration product from 43 to 47 per cent.

The block ores are fairly regular bands of iron carbonate, interstratified with shale or fine sandstone. They are more persistent and uniform in thickness than the other varieties. In Kentucky three persistent beds are recognized having a total outcrop of over 450 miles. The quality of the ore varies inversely with the thickness of the beds, the thinnest beds carrying the best ore. The unaltered carbonate carries from 29 to 34 per cent iron, and the brown ore on the outcrop from 33 to 43 per cent.

The kidney ores, as their name implies, are concretionary in form and occur in certain beds of clay shale, rarely forming continuous layers. They grade into the black-band ores, which are usually more or less closely associated with coal beds and contain carbonaceous matter which gives them a black color. These concretionary forms generally contain the purest iron carbonate and on oxidation at their outcrop yield a correspondingly pure limonite, or brown ore.

In the early history of iron making in the United States this ore belt in Pennsylvania, Ohio, and Kentucky contained a large number of small charcoal furnaces and the aggregate amount of ore produced was very considerable. With the disappearance of the forests the iron industry in this region declined, and the use of these ores has practically ceased. The production was confined largely to the oxidized surface ores, which not only were more easily accessible but gave the best results in the primitive furnaces. While the deposits of this group contain a large aggregate tonnage, practically all of it must be classed as not at present available. The principal reason that the ore can not now be worked at a profit is the fact that the nature of the deposits does not permit operations on a large scale. At only a few points are the beds sufficiently thick and persistent for underground mining, and stripping is therefore the method used. The distance which stripping can be carried into the hillside depends on the slope and the thickness of the bed. An average width of the belt from which the ore can be mined has been assumed as 100 feet, and the average thickness of the ore bed from 10 to 12 inches. The aggregate length of outcrop of the several ore beds has been taken as follows: For Pennsylvania, 866 miles; Ohio, 2,056 miles; and Kentucky, 1,260 miles. With these assumptions the total tonnage of carbonate and associated limonite ores which may ultimately be produced in these three States, and in Tennessee and Alabama, is as follows:

Estimates of Appalachian carbonate ores.

	Available.	Not available.
	Long tons.	*Long tons.*
Pennsylvania	....	46,000,000
Ohio	....	200,000,000
Kentucky	....	60,000,000
Tennessee-Alabama	....	2,000,000

(7) WEST TENNESSEE BROWN ORES.

This group embraces the ore deposits within a broad belt extending from the northern border of Alabama and Mississippi across western Tennessee and Kentucky. This region is a plateau of moderate elevation which has been dissected by the Tennessee River and its tributaries. The rocks underlying the ore-bearing territory are lower Carboniferous cherty limestones. The ore deposits closely resemble the limestone ores of the Appalachian Valley. They vary in size from scattered concretions embedded in surface cherty clay to bodies having a depth of 120 feet or more and containing upward of half a million tons. The larger deposits are confined to slight depressions in the plateau surface, in which deposits of waterworn bowlders suggest the former presence of streams. The ore was doubtless derived from the accumulation during the process of weathering and erosion of iron contained in minerals disseminated through the higher formations. These ores have been mined for many years, supplying a number of local charcoal furnaces and being shipped for mixture with the calcareous Clinton ores of the Chattanooga and Birmingham districts.

In the absence of detailed examination of this ore belt, estimates of ore tonnage contained in these deposits must rest upon a very small foundation of ascertained fact. A few of the deposits have been studied, as those at Russellville, Mannie, and Goodrich, and the estimates for the entire district are based upon these disconnected observations. These estimates place the available ore at 10,000,000 tons, and the ore not now available, chiefly because of the excessive cost of transportation and of working scattered deposits, at 15,000,000 tons.

(8) EAST TEXAS BROWN ORES.

This group of deposits occurs in the northeastern portion of Texas and the adjacent portions of Louisiana and Arkansas. They differ materially in their geologic relations and in the problems of utilization from the brown ores previously described. The region is underlain by Tertiary formations, chiefly unconsolidated sands, clays, and greensands. The ore forms a fairly uniform layer, rarely averaging over 2 feet in thickness, and covering large areas. It is at places exposed at the surface and elsewhere covered by soil and sand to a depth of 6 feet or more. The ore averages about 46 per cent of iron, and is above the Bessemer limit in phosphorus. It is generally high in both silica and alumina. The deposits are probably derived from the oxidation in place of beds and nodules of iron carbonate, although it may be in part due to the concentration of iron derived from the greensand and other iron minerals disseminated through adjacent formations. While these deposits contain in the aggregate a large amount of ore of fairly good grade, its utilization presents somewhat serious difficulties. Owing to the thinness of the deposits the ore can not be excavated with steam shovel or other mechanical devices. The scarcity of water in the region will prevent hydraulicking and also economical washing of the ore, so that only the lump ore can be utilized.

These deposits have been mined at a number of points and have supplied a local furnace for some years. The same region is underlain by beds of lignite, one of which at a depth of about 50 feet has a thickness of over 4 feet. Should it prove practicable to use this lignite in blast-furnace practice, directly or as a gas producer, its occurrence in the immediate vicinity of the ores would prove highly advantageous in their utilization.

In the absence of detailed surveys it is not possible to closely estimate the area of the workable deposits. The total area known to be underlain by the ore-bearing formation is about 500 square miles, and of this probably 50 square miles contain a bed averaging 2 feet in thickness, which is taken as the limit of profitable working at the present time. Upon this basis the district is estimated to contain 260,000,000 tons of available ore, and it is probable that it contains twice this amount of ore that is not now available but will be utilized eventually.

(9) OZARK ORES.

[Based on reports of the Missouri State Survey.]

The Ozark district embraces the southern half of Missouri and a narrow strip along the northern border of Arkansas. It consists of a broad, unsymmetrical, domelike uplift, by which the older rocks are brought to the surface near the center of the district and, dipping outward in all directions, pass under successively younger formations toward its circumference. The oldest rocks in the district are igneous, porphyry and granite, on the irregularly eroded surface of which the Cambrian formations were deposited. The greater part of the district is occupied by cherty, magnesian limestone, with subordinate sandstones and shales.

The district contains four classes of iron ores in deposits of sufficient size to be of commercial importance. These are (1) coarse specular hematite, occurring in veins in porphyry and in associated conglomerate beds; (2) fine specular hematite, occurring in pockets at the contact between Cambrian sandstones and limestones; (3) brown ore, limonite, occurring in pockets in the residual clay and chert derived from the weathering of limestones; and (4) red hematite, occurring as bedded deposits with Carboniferous shales and sandstones. In addition the "Coal Measures" contain occasional thin beds of iron carbonate, but these are not known in deposits of commercial size. Each of these classes of ore being associated with certain geologic formations, their distribution is dependent on the structure of the district. The porphyry ores are confined to a small district in Iron County, practically to the two localities, Iron Mountain and Pilot Knob. The fine hematites are grouped within an area about 50 miles in diameter, chiefly in Phelps and Crawford counties, where the Roubidoux sandstone occupies the surface. The limonite deposits form two irregular groups, the first occupying the basin of the Osage River and the second extending along the southeastern margin of the district. The deposits of the red hematite are less numerous than the other kinds, and occur chiefly along the northern margin of the district.

SPECULAR PORPHYRY HEMATITE.

The interest in these deposits is chiefly historic, since they are now practically exhausted and thorough testing in the most favorable localities has entirely failed to reveal additional deposits. These were the first iron ores worked west of the Mississippi River and supplied several local furnaces, the first of which was built about 1815. They continued to produce up to 1893 and have had a total production of 4,500,000 tons. The history of the development and exhaustion of these deposits is instructive as illustrating the fallacy of the popular belief that many ore bodies are inexhaustible and showing that they are very definitely limited in the amount of ore which they will yield.

SPECULAR SANDSTONE HEMATITE.

These deposits consist of irregularly circular pockets from 300 to 500 feet in diameter, located in the sandstone and extending downward into the underlying limestone. The ore occurs both as bowlders mixed with fragments of sandstone, chert, and residual clay and as a solid, indistinctly bedded mass. The unaltered ore is a dense, fine-grained blue or gray hematite, which near the surface has been changed largely to soft red hematite or to limonite. The better grades contain 55 to 67 per cent of iron and are generally low in phosphorus. In addition there are large amounts of siliceous ore which are not available under present conditions. The yield of individual deposits may be in excess of half a million tons, and unless erosion has cut into deposits of this size they may afford little or no indication of their presence at the surface. In the absence of thorough testing, surface indications are therefore unreliable as a basis for estimates of the ore content of these deposits. A large amount of uncertainty must be present in any estimate of total tonnage, and the figures given are regarded only as roughly approximate. These deposits at present form the chief source of iron-ore production in the Ozark district.

BROWN ORES.

Deposits of this class occur in very large numbers as irregular pockets in the residual material overlying various limestone formations. They are due to the concentration of iron contained in minerals originally disseminated through the rocks which have been removed and were concentrated during the process of weathering and erosion. They are in part also derived from the solution and redeposition at lower levels of other iron ores, as the specular and red hematites. Over 500 localities are listed at which these deposits occur, and while they vary widely in the amount of ore contained, the aggregate tonnage must be very considerable. Owing to the small size of many of these deposits, their distances from transportation places them in the class of ores not at present available. Also, in a considerable proportion of the deposits, the ratio of ore to clay is too low for profitable working at present.

RED HEMATITE.

These ores occur as regularly bedded deposits in certain portions of the lower Carboniferous formations along the northern border of the Ozark district. They are variable in thickness and horizontal extent. The deposits are practically undeveloped, and owing to the low grade of the ore and the thinness and variability of the beds, they can not at present compete with other ores of higher grade and more cheaply mined.

SUMMARY.

The estimates of tonnage contained in the various classes of ore deposits in the Ozark district are summarized in the following table:

Estimates of Ozark ores.

	Available.	Not available.
	Long tons.	*Long tons.*
Sandstone hematite	15,000,000	5,000,000
Brown ore	30,000,000	45,000,000
Red hematite	....	5,000,000

(10) ROCKY MOUNTAIN METAMORPHIC ORES.

This group embraces the deposits of magnetite and specular hematite associated with crystalline schists and gneisses at various localities in the Rocky Mountain region. They are similar in most particulars to the deposits of the same ores in the crystalline metamorphic belt of the Eastern States. They consist of lenticular beds conforming in dip and strike to the foliation of the inclosing rocks and varying greatly in thickness within short distances, both in depth and along the outcrop. Associated with these beds, and evidently derived from them, are occasionally found secondary fragmental deposits, which are sometimes overlain by later sedimentary or igneous formations.

The best-known depcsits of this group occur in the Hartville district, Wyoming, and in the Llano district, Texas. They also occur at various points in Colorado, Nevada, New Mexico, and Arizona, and in general may be expected wherever there are considerable areas of crystalline gneisses and schists. They have been extensively worked in the Hartville district, supplying a part of the ore for the furnaces at Pueblo, Colo., and being used also to some extent for fluxing silver ores. It is probable that a much larger proportion of the deposits of this group are as yet undiscovered than of any other group of iron-ore deposits. In view of the extremely meager information, estimates of their contents have little value. The ore is generally high grade, though sometimes siliceous, but a large proportion of the deposits are not at present available by reason of remoteness from transportation lines and distance from suitable fuel for their reduction.

(11) IGNEOUS CONTACT ORES.

This group is based exclusively upon its geologic relations, and the deposits are widely distributed, though the most of them are located in the Rocky Mountain and Pacific States. The essential characteristics of the deposits are the following: They are steeply dipping, lens-shaped bodies, which closely follow the contact of an intrusive igneous mass and an intruded limestone. They occur partly within the igneous rock as dikelike veins and partly within the limestone, but generally at the immediate contact. The limestone is always altered for a variable distance, sometimes several hundred feet from the contact, the alteration consisting in extreme silicification and the development of lime-bearing metamorphic minerals. The ores are magnetite, or more generally an intimate mixture of magnetite and hematite. They are often altered at the surface to red hematite and to some extent to limonite. The original bedding planes of the limestone are sometimes preserved in the ore body. The gangue consists of quartz and aluminous silicates, in part the recrystallized impurities of the limestone and in part minerals introduced along with the iron. The ores are believed to be due to hot solutions rising from a deep-seated source through fissures in the igneous rock at a period closely following its complete or partial solidification.

CORNWALL DISTRICT, PENNSYLVANIA.

The principal eastern representative of this group is in eastern Pennsylvania, where the ore, chiefly magnetite, has been mined since the early part of the eighteenth century. These deposits, of which the Cornwall mine is considered the type, occur at the contact of intrusive masses of Mesozoic diabase and Cambrian limestone. The more easily accessible portions of the deposits have been mined out, but they are estimated to contain 50,000,000 tons of ore, of which about 15,000,000 tons are considered available under present conditions.

IRON SPRINGS DISTRICT, UTAH.

These are the best known of the western representatives of the group. They are located in southwestern Utah, about 250 miles from Salt Lake. The ore, which consists of both magnetite and specular hematite (70 per cent of the former and 30 per cent of the latter), occurs at or near the contact of laccolithic intrusions of andesite in Carboniferous limestone. The aggregate surface of the known ore bodies is 5,430,000 square feet, and the calculated tonnage to a depth of 130 feet is 40,000,000 tons. While this is the greatest depth at which the ore has been actually observed in prospect pits, a careful consideration of its geologic relations leads to the conclusion that it extends to considerably greater depths, and probably twice the above tonnage may be taken as the amount which is present but not now available. Practically no development has taken place except the sinking of a large number of prospect pits.

OTHER DISTRICTS.

Ore deposits belonging to this group are known to occur at numerous localities throughout the West, but they have not generally been examined in sufficient detail to permit accurate estimates of tonnage being made.

In Utah deposits occur at Bull Valley, about 25 miles southwest of the Iron Springs district and under similar geologic conditions. In California they are found in the Cave Canyon and other districts in San Bernardino County, in the Eagle Mountain district, Riverside County, in Shasta County, and elsewhere. In Nevada large deposits, estimated to contain at least 7,000,000 tons of magnetite and hematite, averaging 63 per cent of iron, are reported to occur in the Lovelocks district, in Humboldt and Churchill counties. Deposits also occur in Lyon County. In Washington deposits which probably belong to this group, although their relations are not known in detail, occur at a number of localities in the northeastern part of the State, in Stevens County. The ores are chiefly magnetite and hematite, though in part altered to limonite.

In Colorado iron-ore deposits occur near Ashcroft, in Pitkin and Gunnison counties, and in the White Pine and Cebolla districts, in Gunnison County. Those of the Ashcroft district occur on both sides of the Elk Mountains, at elevations between 11,000 and 12,000 feet above tide. The deposits are associated with limestones and igneous intrusives. They are of considerable size, the one on the northwest side of the divide being at least 300 feet on the strike and from 40 to 122 feet thick. Its total depth is not known, but it is proved to be at least 100 feet. The greater part of the ore is high in iron and sulphur, but low in phosphorus.

In New Mexico iron-ore deposits occur at Chupadera Mesa and at Fierro, in Grant County. The latter locality has been worked for some years, furnishing a large amount of ore for the Pueblo furnaces. The ore is associated with limestones and igneous intrusions, forming lenses at or near the contact between the two. It is accompanied with metamorphic minerals, as epidote and garnet, which are developed in the contact zone in great abundance. The ore is magnetite with subordinate amounts of hematite, and usually contains a small amount of copper. The greater part of the easily accessible high-grade ore has been mined out.

COMMERCIAL CLASSIFICATION AND SUMMARY OF ESTIMATES.

While the foregoing classification and grouping of the iron-ore deposits is a convenient one for purposes of description and for discussion of the basis and value of tonnage estimates, the grouping does not correspond with commercial conditions, and the estimates already given are therefore summarized by commercial grades and districts in the following table:

Estimates of iron-ore supplies of the United States.

Commercial districts (States).	Magnetite ores.			
	Nontitaniferous.		Titaniferous.	
	Available.	Not available.	Available.	Not available.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
1. Northeastern	160,000,000	111,500,000	90,000,000	100,000,000
2. Southeastern	[a] 12,500,000	23,000,000		
3. Lake Superior		4,500,000,000		25,000,000
4. Mississippi Valley				
5. Rocky Mountain	[a] 51,485,000	[a] 115,440,000		1,500,000
6. Pacific Slope	[a] 68,950,000	11,800,000		2,000,000
Total	292,935,000	4,761,740,000	90,000,000	128,500,000

Commercial districts (States).	Hematite ores.			
	Specular and red.		Clinton.	
	Available.	Not available.	Available.	Not available.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*
1. Northeastern	2,000,000	2,000,000	35,000,000	620,000,000
2. Southeastern	8,000,000	53,000,000	463,540,000	970,500,000
3. Lake Superior	3,500,000,000	67,475,000,000	10,000,000	30,000,000
4. Mississippi Valley	15,000,000	10,000,000		
5. Rocky Mountain	4,275,000	2,100,000		
6. Pacific Slope		10,000,000		
Total	3,529,275,000	67,552,100,000	508,540,000	1,620,500,000

Commercial districts (States).	Brown ores.		Carbonate ores.		Total supplies.	
	Available.	Not Available.	Available.	Not Available.	Available.	Not Available.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
1. Northeastern	11,000,000	13,500,000		248,000,000	298,000,000	1,095,000,000
2. Southeastern	54,400,000	168,000,000		62,000,000	538,440,000	1,276,500,000
3. Lake Superior					3,510,000,000	72,030,000,000
4. Mississippi Valley	300,000,000	560,000,000			315,000,000	570,000,000
5. Rocky Mountain	2,000,000	1,625,000			57,760,000	120,665,000
6. Pacific Slope		105,000			68,950,000	23,905,000
Total	367,400,000	743,230,000		310,000,000	4,788,150,000	75,116,070,000

[a] Includes some hematite.

1. Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Ohio.
2. Virginia, West Virginia, eastern Kentucky, North Carolina, South Carolina, Georgia, Alabama, east Tennessee.
3. Michigan, Minnesota, Wisconsin.
4. Northwest Alabama, west Tennessee, west Kentucky, Iowa, Missouri, Arkansas, east Texas.
5. Montana, Idaho, Wyoming, Colorado, Utah, Nevada, New Mexico, west Texas, Arizona.
6. Washington, Oregon, California.

FOREIGN IRON-ORE SUPPLIES.

In addition to the ore supplies included in the table given above, certain foreign deposits are so situated that they must depend, at least to a considerable extent, upon the American market, and are therefore to be considered practically a part of the available reserves. The most important of these sources of foreign supply are located in Canada, Newfoundland, Cuba, and Mexico. None of these countrics has an abundant fuel supply, and therefore either the fuel must be imported or the ore exported. The history of the iron industry indicates that the latter is most likely to occur, particularly when the industry is already established and the chief market for the finished product is near the fuel supply. This tendency may be interrupted by artificial means, such as bonuses and tariffs, but such interference with the natural course of industrial development is only temporary, and in the long run the industry will gravitate to the point of the lowest cost of production.

CANADIAN ORES.

Recent explorations have shown the existence of considerable areas of the iron-bearing formations on the north shore of Lake Superior. The total tonnage of the iron formation in the Animikie, Michipicoten, and other north-shore districts is calculated at 93,600,000,000 tons. If the same proportion of this total be considered low-grade ore as in the Michigan and Minnesota districts it will amount to about 20,000,000,000 tons. Since these north-shore districts are not as yet thoroughly prospected, the ratio between high and low grade ores can not be definitely determined, but it is almost certainly much lower than in the Michigan and Minnesota districts. The best estimate of ore now available in these Canadian districts is 9,000,000 tons.

Deposits of iron ore of the igneous contact type are known to occur in British Columbia, and those on Texada Island have been mined to some extent. These deposits are estimated to contain at least 30,000,000 tons of ore of present commercial grade and probably a considerably larger amount of low-grade and deep ore not now available.

NEWFOUNDLAND ORES.

The most important of these are Clinton ores occurring on Belle Isle. Their area is definitely known and the doubtful factors are the proportion of ore below present commercial grade and the amount of available ore in beds known to extend under the ocean. The supply of available ore has been estimated at 30,000,000 tons, and the amount not now available may be several times this amount.

MEXICAN ORES.

Large deposits of iron ore are known to occur in various parts of Mexico. They are chiefly of the igneous contact and gossan types, and no estimate of any value can be made of their available tonnage. Remoteness from centers of iron production will prevent their extensive exploitation for the present, and they are therefore to be regarded as wholly within the unavailable class.

CUBAN ORES.

By far the most important foreign source of iron ore, measured by the extent of the supplies and their accessibility, is Cuba. The deposits are of two kinds, specular hematites of the Santiago district and brown limonites of the Mayari, Moa, Baracoa, Cubitas, and Pinar del Rio districts. The hematites have been worked extensively since 1884, and for a number of years have furnished more than 50 per cent of the total iron-ore imports. They are estimated to contain about 9,000,000 tons of ore, about half of which is actually measured.

The limonites are widespread residual deposits derived from the weathering of igneous rocks. The ore contains from 43 to 52 per cent of iron, phosphorus below the Bessemer limit, and between 1 and 2 per cent of chromium. These deposits are as yet practically undeveloped, but the more important ones have been fairly well prospected, and it is estimated that they contain an aggregate of 3,000,000,000 tons, at least one-third and possibly one-half of which may be regarded as now available. Most of the deposits are located near the northern coast of the island, so that they have the advantage of cheap water transportation to all parts of the Atlantic seaboard. They are without question destined to play an important rôle in the iron industry of the United States.

SUMMARY OF FOREIGN SUPPLIES.

The total estimated foreign supplies of ore sufficiently high-grade and accessible to mining and transportation to be at present available, and so located as to affect the iron industry of the United States, are shown in the following table:

Estimated foreign iron ores.

	Long tons.
Canada:	
British Columbia, magnetite chiefly	30,000,000
Lake Superior district, hematite chiefly	9,000,000
Nova Scotia, Clinton hematite	4,000,000
Newfoundland, Clinton hematite	30,000,000
Cuba:	
Santiago district, hematite	5,000,000
Mayari, Moa, Baracoa, Cubitas, and Pinar del Rio districts (limonite)	1,500,000,000
Total	1,578,000,000

IMPORTS AND EXPORTS.

The total imports of iron ore since 1889 have been 3 per cent of the domestic production for the same period. They have shown great annual fluctuations, responding quickly to changes in industrial conditions. Since 1904 there has been a steady and rapid increase in imports, and this increase may be expected to continue in the future even more rapidly with the expanding development of the Cuban limonite deposits.

The extent to which foreign ores are now supplying the market is shown by the following table of imports:

Imports of iron ore from foreign countries, 1889–1907.

Year.	Cuba.	Newfoundland and Labrador.	Quebec, Ontario, etc.	Spain.	Other countries.[a]	Total.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
1889	243,255	14,450	4,091	298,568	293,209	853,573
1890	351,814	6,320	22,211	512,933	353,552	1,246,830
1891	257,189	....	2,126	323,771	329,778	912,864
1892	307,115	....	8,606	236,957	253,907	806,585
1893	349,977	....	372	99,640	76,962	526,951
1894	140,025	....	443	15,067	11,772	167,307
1895	367,255	....	....	77,594	79,304	524,153
1896	380,551	20,800	....	121,132	160,323	682,806
1897	383,820	29,250	....	66,193	10,707	489,970
1898	165,623	....	....	13,335	8,250	187,208
1899	360,813	77,970	....	145,206	90,093	674,082
1900	431,265	140,535	5,588	253,694	66,749	897,831
1901	526,583	[b] 79,360	163,383	180,810	16,814	966,950
1902	696,375	81,920	203,824	153,527	29,824	1,165,470
1903	613,585	[b] 86,730	169,681	94,720	15,724	980,440
1904	364,630	5,400	77,887	36,810	2,886	487,613
1905	539,935	5,600	104,096	191,861	4,159	845,651
1906	639,362	[b] 125,395	57,890	171,870	65,873	1,060,390
1907	657,133	89,685	26,878	296,318	159,154	1,229,168
Total	7,776,305	763,415	847,076	3,290,006	2,029,040	14,705,842

[a] Belgium, Brazil, British Columbia, England, France, French Africa, French West Indies, Germany, Greece, Italy, Mexico, Netherlands, New Brunswick, Norway, Nova Scotia, Oceania, Portugal, Sweden, Turkey in Asia, Turkey in Europe, Venezuela, etc.
[b] Includes Newfoundland only.

The exportation of iron ores has fortunately never assumed large proportions, as shown by the following table:

Exports of iron ore from the United States, 1899–1907.

Year.	Quantity.	Value.
	Long tons.	
1899	40,665	$76,287
1900	31,460	154,756
1901	64,703	163,465
1902	88,445	294,168
1903	80,611	255,728
1904	213,865	458,823
1905	208,017	530,457
1906	265,240	771,839
1907	278,208	763,422
Total	1,271,214	3,468,945

This export consists chiefly of Lake Superior ores shipped to Canadian furnaces for mixture with local ores. It contains also some high-phosphorus ores from the Adirondack district shipped to Germany. This movement has practically ceased, owing to increased home demand for these ores.

WASTE IN MINING AND REDUCTION.

Where iron ore occurs in the form of bedded deposits and is mined underground, waste is apt to occur from the same causes as in coal mining. These are the leaving of pillars to support the roof, often unnecessarily large, the leaving of low-grade ore in the mine where it can subsequently be recovered only with difficulty, if at all, and the breaking down of an overlying bed where the lower of two beds in the same territory is mined first. These sources of waste are confined largely to the Clinton ores, and the available facts are insufficient for closely estimating its amount, but the proportion of recovery varies with local conditions between 75 and 90 per cent and is undoubtedly increasing with improvement in mining methods. In computing the available tonnage of the Clinton ores an average recovery of 75 per cent has been assumed. Portions of the Clinton ore beds at present considered of no value because of shale partings and consequently left in the ground might be mined at many points if the shale could be separated from the ore economically. Improvement in cleaning and concentrating methods will undoubtedly make the recovery of much ore of this character possible. In the steeply dipping magnetite and hematite beds practically all ore up to the required grade is mined out, and the ground is generally left in such condition that the mines can be reopened for the recovery of lower-grade ores.

In surface workings waste is confined largely to small operations where quick returns are required, and systematic development is impossible. In such cases much ore is lost by dumping barren strippings and low-grade ore together, so that it can be recovered only with difficulty, if at all. Where the operations are on a large enough scale to warrant the installation of mechanical excavators, and a proper ore-dressing plant, this waste does not occur and practically all the ore in a deposit is recovered. Some waste of finely divided ore occurs in the process of washing brown ores to remove the associated clay, and there is still room for improvement in operations of this kind. If it becomes necessary to mine material which is below the grade of present requirements, but which contains enough iron values to make it a possible ore in the future, such material is stacked so that it will be available at any future time. This policy has been most consistently followed in the Lake Superior district, and when such low-grade ores are required large amounts will be available merely at the cost of loading on the cars.

In the early days of iron making an appreciable part of the iron in the ores went into the slag and was permanently lost. Blast-furnace practice, however, has been so greatly improved in recent years that this source of waste is eliminated and practically all of the iron in the ore is now recovered.

PRODUCTION AND USE OF IRON ORES.

The beginning of the iron industry in America dates from 1645, when a furnace and forge were built at Lynn, in the province of Massachusetts Bay. In the century following a large number of small furnaces and bloomeries were operated in the New England colonies, using bog ores almost exclusively, and during this period Massachusetts was the chief iron producer. In 1734 the richer brown ores of western Connecticut and southern New York were opened and largely replaced the bog ores. The manufacture of iron was begun in eastern Pennsylvania in 1716, and a few years later in northern New Jersey, using the rich magnetites of that region. The industry had a rapid growth, notwithstanding the restriction placed upon it, and at the time of the Revolution there were over 140 furnaces and bloomeries in operation in this district.

In the fifty years preceding the Revolution a number of furnaces and forges were in operation in Maryland, Virginia, and the Carolinas, located for the most part on the tide-water streams of the coastal plain and using the brown ores associated in small quantities with the clays and sands of the coastal formations. The deposits of magnetite in the crystalline rocks of the Piedmont were also worked during this period to a slight extent.

After the close of the Revolution the iron industry expanded rapidly, following the westward progress of settlement, and had reached western Pennsylvania and the Appalachian Valley of Virginia and Tennessee before the close of the eighteenth century. In the first third of the nineteenth century it had reached as far west as Missouri and north to Michigan. During this period conditions favored a wide distribution of the industry. Charcoal was the only fuel used, and this could always be obtained in the immediate vicinity of the ores. Transportation facilities were very poor, and the small furnaces so situated as to supply the local demand, even working on inferior ores, could compete with the older establishments at a distance. About 1840 a revolution was effected in the iron-making industry by the introduction of anthracite and bituminous coal as a furnace fuel. The capacity of the furnaces was rapidly increased, and with improvement in transportation facilities the industry was concentrated at a relatively few points advantageously located with reference to the new fuel supply. Under the changed conditions the ore was brought to the fuel, hence only the best ore and the largest deposits were worked, and many districts, as Ohio and Kentucky, which had been heavy producers, were practically abandoned. With the decrease in average iron content of ores going into the furnaces, due to the depletion of the richest deposits, there is at present a notable tendency toward decentralization of the industry and a consequent reopening of abandoned ore deposits, though it will never revert to the conditions which prevailed during the charcoal period.

The statistics of iron production during the early years of the industry were not collected, and the total amount of iron ore consumed can not be determined. Not until 1889 were annual statistics of ore production collected, though they are available for the two preceding census years 1870 and 1880, and the annual production of intermediate years may be derived from the known production of pig iron as far back as 1870. Basing an estimate upon the average pig iron production shown for census years prior to 1870, the total iron ore produced from 1810 to 1869 was approximately 49,656,000 tons, and on the annual production of pig iron from 1870 to 1888 it was 153,758,000 tons. These amounts added to the 475,162,000 tons produced from 1889 to 1907 give a grand total of 678,576,000 tons produced since 1810. The amount produced during the Colonial and Revolutionary periods and up to the third census in 1810 is so small in comparison with the total production since that time as to be a negligible quantity.

In deducing the iron ore production from the production of pig iron, it should be borne in mind that a small proportion of this iron was made from imported ores and also that some pig iron is made from other materials than natural ores, as blue billy, zinc residues, rolling-mill cinder, scrap, etc. On the other hand, iron ore is used for other purposes, as in the manufacture of paint, as a fix or fettling in puddling furnaces, and as a flux in silver smelting, and the amount so used practically offsets the amount of material other than iron ore charged into the blast furnaces.

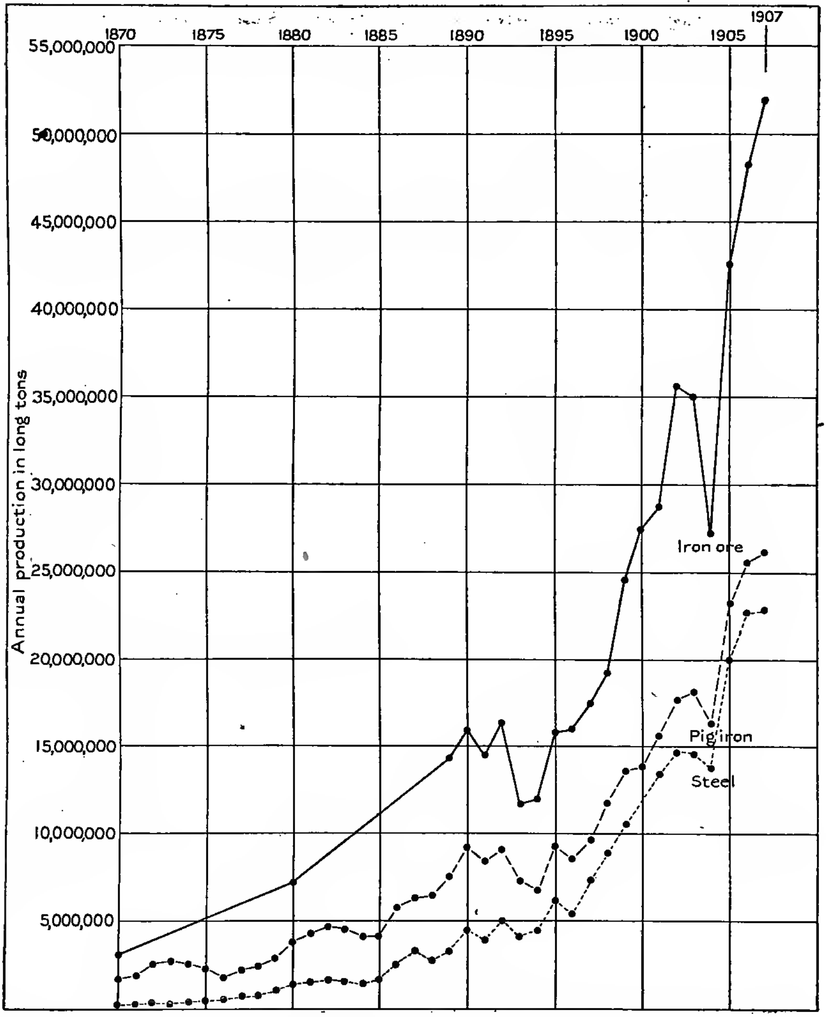


FIG. 1.—Curve showing the production of iron ore, pig iron, and steel in the United States, 1870–1907, in long tons.

The production of iron ore from 1870 to 1907, inclusive, is shown on the accompanying diagram along with the production of pig iron and steel for the same period.

The curve representing the production of pig iron shows more fluctuations than the ore curve, and that representing production of steel more than the pig-iron curve. In other words, the production of steel responds most promptly to varying industrial conditions. Thus the production of steel in 1907 shows practically no increase over 1906, while the rate of increase in ore is above the average for the preceding eighteen years. This is explained by the fact that the industrial depression of 1907 came so late in the year that it only slightly affected the output of iron ore, particularly in the Lake Superior district, where mining is more active in summer than in winter. It is practically certain, however, that the output of ore for 1908 will show a decided decrease similar to, and probably larger, than that which marked the years 1893–94 and 1904. The years 1892, 1902, and 1907 occupy maximum points in the curve, and each is followed by a decided drop and rapid recovery far beyond the preceding maximum. It may be safely predicted that the curve will resume its upward trend in 1909 after the drop of 1908.

The distribution of the production since 1889 among the varieties of ore enumerated in the chemical classification is shown in the following table:

Production of iron ores in the United States, by varieties, 1889–1907.

Year.	Magnetite.	Hematite.	Brown ore.	Carbonate.	Total.
	Long tons.	*Long tons.*	*Long tons.*	*Long tons.*	*Long tons.*
1889	2,506,415	9,056,288	2,523,087	432,251	14,518,041
1890	2,570,838	10,527,650	2,559,938	377,617	16,036,043
1891	2,317,108	9,327,398	2,757,564	189,108	14,591,178
1892	1,971,965	11,646,619	2,485,101	192,981	16,296,666
1893	1,330,886	8,272,637	1,849,272	134,834	11,587,629
1894	972,219	9,347,434	1,472,748	87,278	11,879,679
1895	1,268,222	12,513,995	2,102,358	73,039	15,957,614
1896	1,211,526	12,576,288	2,126,212	91,423	16,005,449
1897	1,059,479	14,413,318	1,961,954	83,295	17,518,046
1898	1,237,978	16,150,684	1,989,681	55,373	19,433,716
1899	1,727,430	20,004,399	2,869,785	81,559	24,683,173
1900	1,537,551	22,708,274	3,231,089	76,247	27,553,161
1901	1,813,076	24,006,025	3,016,715	51,663	28,887,479
1902	1,688,860	30,532,149	3,305,484	27,642	35,554,135
1903	1,575,422	30,328,654	3,080,399	34,833	35,019,308
1904	1,638,846	23,839,477	2,146,795	19,212	27,644,330
1905	2,390,417	37,567,055	2,546,662	21,999	42,526,133
1906	2,469,294	42,481,375	2,781,063	17,996	47,749,728
1907	2,679,067	46,060,486	2,957,477	23,589	51,720,619
Total	33,966,599	391,360,205	47,763,384	2,071,939	475,162,127
Percentage of totals for nineteen years	7.1	82.4	10.1	0.4	
Percentage of total for 1907	5.2	89.1	5.7		

The present relative importance of the several varieties is shown by the percentage and also the increasing importance of the hematite as compared with the other varieties. The combined total productions of brown ore and carbonate for the nineteen years is 2,000,000 tons less than the total production of all varieties for the year 1907.

The distribution of production for 1906 and 1907 among the six commercial districts is shown in the following table:

Production of iron ores in the United States, by commercial districts, in 1906 and 1907.

District.	1906.		1907.	
	Quantity.	Percentage of total.	Quantity.	Percentage of total.
	Long tons.		*Long tons.*	
1. Northeastern	2,582,666	5.40	2,822,822	5.45
2. Southeastern	6,208,140	13.00	6,197,360	12.00
3. Lake Superior	38,035,084	79.66	41,638,744	80.50
4. Mississippi Valley	117,570	.25	230,435	.45
5. Rocky Mountain	806,268	1.70	831,258	1.60
6. Pacific slope	(a)		(a)	
Total	47,749,728	100.00	51,720,619	100.00

[a] The small production of California and Washington is included in the production of the Rocky Mountain district.

These figures indicate the commanding position of the Lake Superior district in the iron industry with 79.66 and 80.60 per cent of the total production for the two years.

DURATION OF THE IRON-ORE SUPPLY.

Predictions of the date of exhaustion of the iron-ore reserves involve a number of unknown factors, each of which adds to the uncertainty of the result. Among these factors the following may be mentioned:

1. The uncertainties of the estimates of reserves and the difficulty of fixing the ratio of the two classes have been fully explained in the sections devoted to the description of the ore deposits.

2. The extent to which imported ores will supplement the domestic supply can not be foretold, but it will be an increasingly important factor.

3. The extent to which the reserves will be increased by the discovery of new ore bodies can not be estimated, but it is highly improbable that all the important iron-ore deposits are now known.

4. The ores of the first class will not be entirely exhausted before utilization of the second class begins, and changing conditions, particularly of transportation and metallurgy, will continually shift the line dividing the two classes.

5. The stock of metal which can be reworked is constantly increasing and must eventually reduce the demand for metal obtained directly from the ores.

6. The substitution of other materials for metal now used for certain purposes, particularly for construction, will reduce the consumption to an extent which can not be even approximately estimated, and, on the other hand, the proportion of structures into which iron enters as an important constituent will undoubtedly increase.

7. The per capita consumption of iron ore has shown a rapid increase since the beginning of the iron industry. For 1907 and the four preceding census years it has been as follows: 1870, 180 pounds; 1880, 313 pounds; 1890, 560 pounds; 1900, 806 pounds; and 1907, 1,344 pounds.

8. The increasing cost of iron due to the increase in cost of fuel and the use of lower-grade ores requiring an increased amount of fuel per ton of iron smelted, will induce greater economy in the use of the metal; on the other hand, improvements in metallurgy will tend to secure a larger yield of metal for a given expenditure of fuel and power and may substitute low-grade fuel for the higher-grade coal now required in the blast furnace.

The most striking feature of the iron-ore production curve is the remarkable rate of increase shown in the period covered. Taking the production since 1870 by decades and estimating the last two years of the present decade, 1908 and 1909, the percentage rate of increase for each decade over the one preceding is shown in the following table:

Production of iron ore by decades and rate of increase.

Decade.	Quantity.	Percentage of increase.
	Long tons.	
1870-1879	43,770,527	....
1880-1889	91,043,854	108.0
1890-1899	163,989,193	80.1
1900-1909	[a] 392,000,000	138.0

[a] Approximate.

Each of the above decades, as shown by the production curve, contains a depression in which there was an actual decrease in production, so that they may be taken as fairly representing the tendency of the industry. These rates of increase are such that they do not permit the construction of a curve on which predictions for the future can be based. A comparison of the first and second rates, 108 and 80.1, would indicate a rapid decrease in the rate of increase, which, if continued, would have placed the date of maximum production about 1930. But a comparison of the second and third rates, 80.1 and 138, would indicate a rapid increase in the rate of increase. If the average rate of increase by decades, 108.7 per cent, should be continued, it would require the production in the next three decades of 6,088,000,000 tons. But the ore supply now available in the United States is estimated at 4,788,000,000 tons, which is only 78 per cent of the amount needed on this assumption. It is evident, therefore, that the present average rate of increase in production of high-grade ores can not continue even for the next thirty years, and that before 1940 the production must already have reached a maximum and begun to decline, and a very large use must be made of low-grade ores not now classed as available. The second condition, with its consequent greatly increased cost of iron, is the only thing which can prevent a decline in the iron industry, measured by the amount of pig iron produced, within the next thirty years, unless there is in the meantime very greatly increased importation of foreign ores.

In view of the many factors entering into the problem, the tendency of which is not always determinable, to say nothing of the weight that should be given them, any further prediction as to the date of exhaustion of the iron-ore supplies is so uncertain as to be wholly unprofitable and unwarranted.

RESOURCES OF THE UNITED STATES IN GOLD, SILVER, COPPER, LEAD, AND ZINC.

By W. Lindgren,
United States Geological Survey.

INTRODUCTION.

The ores of gold, silver, copper, lead, and zinc occur as a rule in localized deposits of varying form, depth, tenor, and geologic relations. There are no wide areas underlain by strata of ore with maintained characteristics. The ore deposits are exceptional occurrences. They are concentrated, it is true, in a number of localities, but the bodies are ordinarily of very irregular form, and it is difficult to predict what each new level in a shaft, each new drift on a level, will disclose. Some of the large companies mining copper, lead, or zinc ores have extensive reserves blocked out by actual development work or by borings, but the ore developed is rarely sufficient for more than a few years' work. The majority of the companies would undoubtedly decline to furnish detailed information on this subject.

The distribution of values is even more capricious in precious-metal mines than in base-metal mines, and in the case of gold the number of companies operating lode mines with large reserves can be counted on the fingers. Concerning deposits of gold-bearing gravels or placers, a somewhat more accurate statement can be made as to the probable extent of resources. These remarks serve to make clear the impossibility of ascertaining even the approximate extent of the total supply of metallic ores. The best that can be done is to forecast in a rough way the probabilities of the immediate future on the basis of the experience of the past. In doing so, it is well to bear in mind that many of the predictions ventured on this subject during the last fifty years by able men have proved very wide of the mark.

The conclusions reached in this report are based chiefly on investigations by the geologists of the United States Geological Survey.

MINERAL LANDS OF THE UNITED STATES.

The mineral-bearing lands still owned by the United States are largely confined to the Cordilleran States. The mineral lands of the Southern Appalachian States are privately owned, and as far as the total production is concerned they cut a small figure. Likewise, the copper-bearing lands of Michigan and the lead-zinc lands of Missouri and other States of the central valley have passed into private hands. There remain the States of Colorado, Wyoming, Montana, Idaho, Utah, Nevada, Washington, Oregon, and California, as well as the Territories of Alaska, Arizona, and New Mexico, in which there still exists a large aggregate area of mineral land belonging to the United States. The extent of the mineral land of the United States still owned by the Federal Government is an unknown quantity because (1) the mineral lands have never been segregated and surveyed, and (2) a very large acreage is simply held by assessment work, and the present laws do not require that such claims shall be surveyed or registered. It is true that the majority of claims on which valuable mines have been developed have passed to patent. But there are thousands, in fact, hundreds of thousands of claims on which mineral has been discovered, which are held by annual assessment work, and of which the General Land Office has no record whatever. Even many important producing mines, and practically all placer mines of Alaska, are thus held. This condition is made much worse by the fact that according to present laws anyone—individual or company—can locate an unlimited number of claims provided the assessment work is performed. As no assessment work is required until a year to two years after discovery, this rule works out so that a newly discovered camp is completely covered by locations by the first comers, and its growth may be seriously interfered with. In case of specially valuable discoveries the early arrivals are thus granted an unreasonable privilege which is always abused. The process is well known throughout the West, and is popularly known as "claim hogging."

The first steps toward ascertaining the area of mineral land still belonging to the United States would seem to be: (1) Survey and segregation of mineral lands; (2) registration of all mineral claims at the land office of the district.

Any estimates on the basis of available data are useless.

The first requirement, segregation of mineral lands, is no doubt easier to demand than to execute. There is no possibility, as with coal deposits, to segregate large areas with the confident knowledge that the mineral exists below them. For instance, a mountain range may present a favorable aspect from a geologic standpoint for the occurrence of metals, and yet no deposits may be found in it except perhaps within one limited area. However, the possibility always remains that some careful and deeper prospecting may reveal ores in the part hitherto considered barren.

A worse complication is involved when the land is valuable for several purposes. It may be good agricultural land; even if situated in the mountain regions it may, as is frequently the case in California, be valuable for horticulture and viticulture, or for pasture. Here is a conflict between permanent and temporary value. The land will always produce fruits, but the gold deposit below it will, in all probability, be exhausted in a limited time, very soon, indeed, in the case of many buried gravel channels. Such conflicts have caused much loss and annoyance in California. How can these two values be compared and measured?

A difficulty even more troublesome arises when the land is valuable for both its mineral and its forest. Here, however, we have to measure two more commensurate values, both of more temporary character than in case of agricultural lands. The value of the forest can usually be measured with some accuracy. The value of the mineral on the same land can usually not be measured with exactness. Very often the former will exceed the latter, as far as surface developments go, and then the question arises whether it is justifiable to interfere with free prospecting and search for metals in order to more effectively preserve the forests.

It would seem that the present interminable conflicts could be avoided only by a separation of the mineral and forest rights, while retaining for agricultural patents the right to possible later discoveries underneath the ground. The forest lands have great value, and as long as human nature remains what it is even the bona fide miner will continually attempt to gain possession of them by unduly extending his mineral locations. Many mining districts are covered with a scant growth of forest, barely enough for the miner's needs for timber and fuel. Such lands should not be classified as forests.

WASTE.

The prevention of waste in mining and reduction processes is a most important subject. Whatever our views of future necessities, it is clearly not right to carelessly waste the metallic treasures of the earth, and in this direction much can be accomplished. The loss is rather in processes of concentration and reduction than in mining. In some cases pillars of ore are left, but the shape of the deposits is generally such that all the ore can be extracted without much loss. In industries like copper mining, where the term "ore" has rapidly changed its meaning within the last decade—where, in other words, ore containing 1, 2, or 3 per cent of copper can now be mined profitably where it was formerly considered waste—it is clear that large bodies must be left now which later may possibly be extracted with profit. But this ore is, of course, not lost unless the whole mine goes to wreck.

In concentrating and milling the greatest losses occur and the percentage of these is largest in the low-grade deposits. In the earlier days of gold and silver milling enormous amounts of rich tailings were sent down the creeks and gulches and permanently lost, largely because of conviction that the values could not be recovered, partly perhaps because of disinclination to let it be known that the tailings contained any values. Matters have changed in this respect, and tailings are now generally stored with a view to possible reworking. No doubt the States could aid this practice of economy by legal requirement of such storage, a policy which besides is desirable in order to avoid contamination of the water supply.

The losses of gold, silver, copper, and lead in smelting are generally not large, and, moreover, the slag is necessarily and easily stored. In many cases the slags of earlier years have been worked over. By far the greatest losses take place in the concentration of copper, lead, and zinc ores. They probably reach their maximum in zinc ores or in copper ores with soft metallic minerals like chalcocite, and here often attain 30 per cent or even 40 per cent. These operations are also conducted on a large scale, making storage of tailings difficult, but the same principle should be applied by legal requirements wherever possible. Somewhat better conditions now prevail in Missouri than formerly, but some years ago it was not at all uncommon to have losses in zinc concentration reaching 40 per cent.

No doubt it will be impracticable, under our system of government, to compel mine owners to prevent unnecessary waste by prescribing certain working methods. Probably no European state has ever gone so far. Storage of tailings will probably prove to be the best remedy if it can be legally enforced.

It is perhaps in the utilization of by-products that we have most to learn, but the standpoint is naturally taken by miners and smelting men that if it can not be done with profit it had better not be done at all. I refer specially to the smelter fumes and to the extremely large quantities of sulphur and arsenic that are driven off in the air, sometimes with great damage to the surrounding agricultural districts. The case of arsenic is especially interesting. The statement is made by F. L. Hess [a] that—

Enormous quantities of arsenic in fumes continually escape from the smelters of the country, while at present comparatively little arsenic is saved. Harkins and Swain (Jour. Am. Chem. Soc., vol. 19, 1907, pp. 970–998) state that in August, 1905 (when the experiments were made), from the Washoe smelter, which works exclusively upon Butte copper ores, 59,270 pounds of arsenic trioxide per day were passing through the stack. This is equivalent to 10,817 short tons per year, and is exclusive of what arsenic trioxide was saved from the flues. At 5 cents per pound, the lowest price for which white arsenic sold in 1907, this waste product of one year would be valued at $1,081,700. The waste arsenical fumes at this plant alone amount to more than six times the domestic saving of arsenic trioxide, and to much more than the combined production and imports of arsenic in the United States each year.

At the Butte reduction works and the Great Falls smelter other great quantities of more or less arsenical Butte copper ores are treated, from which no saving of arsenic is known to have been made, and from which the losses must be very great.

In Utah both the Bingham and the Tintic copper ores are arsenical, and no saving has yet been made from them, though immense quantities of ore are smelted.

It is recognized that in handling a low-priced product like arsenic, saving can not be carried to extreme refinement without becoming unprofitable. However, arsenic is now being extracted from sulphuric acid at a number of establishments in England, and both products are cheap articles. If even one-half of the arsenic wasted were saved, the market in this country would be glutted. However, without taking account of the possibility of greater demand, if there were a greater supply at a somewhat lower price, there will in time probably be some plan devised for the better saving of smelter fumes, through the operation of which it will be unnecessary for this country to import arsenic while so much is continually being wasted.

Smelter fumes occupy a similar position to tailings in mills, but they can not, of course, be stored. On the contrary, they spread over the country, frequently damaging the vegetation near the smelter, and the compulsory saving of the sulphur and arsenic contained will probably soon, in most cases, be required by law.

In many cases the waste in mining and milling is the result of ignorance. Dissemination of knowledge and investigation of methods by bureaus of the Federal Government and the States will do much to check the waste.

GENERAL CONCLUSIONS.

The individual reports on the separate metals will show that the resources in each case are very large, but that they can not (with few exceptions) be measured with any accuracy. To give definite

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[a] Mineral Resources, U. S., for 1907, separate on "Antimony and arsenic," p. 9.

figures representing our metal supply is quite out of the question. It will be shown that our resources of silver, copper, and zinc are very large and that a moderate rate of increase in production can be maintained probably for the next twenty years at least. In case of lead it is not probable that the production can be very greatly increased. While it is true that, with a continuation of the present increasing rate of production, the known reserves, workable under present conditions, will be exhausted before the middle of the present century, this prediction should not be announced without important qualifying clauses. The nature of the case prevents a full knowledge of our resources. They are developed by mining operations only, and exploration does not materially anticipate unusual demand. Ten years ago a review of our metallic wealth would have revealed a far greater shortage in the supply of metals than is now believed to exist, and it is probable that, in case of some metals at least, ten years from now our resources will be known to be greater than they are at present. The higher grade of ores of copper and lead are growing scarce, but improvements in technologic processes, by lowering the cost of reduction, have added great quantities of lower-grade material to our available ore supply, and will probably continue to do so. With increasing demands quantities of old metals will be returned to use. The importance of this factor is great, but it is difficult to measure. In case of gold it does not seem likely that, on the basis of present developments and processes, our production can be made to greatly exceed $110,000,000 per annum for the next twenty years. And on the same basis it would seem likely that after some such period the gold production would gradually decrease.

If we were sure that the development of the world would proceed indefinitely on the same lines as those of to-day; that metals would have the same value; that the same metals would be used for the same purposes; then it might be possible (to use an expression of Professor De Launay[a]) "to strike a balance between us and our descendants." We have not this knowledge. We may forecast what is likely to happen and what our needs will be in the metal industry, for the next ten, twenty, possibly fifty years. The conditions and developments in the more distant future are completely beyond us.

It is reasonably certain that the industrial development of the world will continue on an ever increasing scale. But who can tell us what methods and materials will be used, and what new discoveries in little explored continents will disclose? Substances now eagerly sought may then be of little value; reserves established by the States may be useless and simply serve to restrict the present development. Legislative interference with production of metals is likely to be futile and probably can not in the long run successfully interfere with the operation of economic principles based on laws of supply and demand.

GOLD.

PRODUCTION OF THE UNITED STATES.

Since 1892 the gold production of the United States has increased at a very rapid rate. An output of $60,000,000 was recorded in 1852

[a] De Launay, L., La conquête minérale, Paris, 1908, p. 379 et seq.

and 1854, shortly after the discovery of the California placers. From that time the production decreased gradually to $30,000,000 in 1883 and 1884 and then rose slightly, remaining at about $33,000,000 from 1885 to 1892. The effect of the Cripple Creek discoveries and of the application of the cyanide process became apparent after 1892 and the production steadily mounted to about $80,000,000 in 1902. A serious falling off in Colorado reduced the total in 1903 to $73,500,000, but during the next four years in consequence of the discoveries in Alaska and the development of the dredging industry in California, there was a renewed rise which culminated in a production of over $94,000,000 in 1906.

In 1907 the output fell to $90,400,000, but a further decline is not probable for 1908. The causes of the decrease in 1907 were the generally disturbed financial conditions, labor troubles, and a scarcity of water in Alaska.

The output of the United States is shown in the accompanying diagram.

PRODUCTION OF THE WORLD.

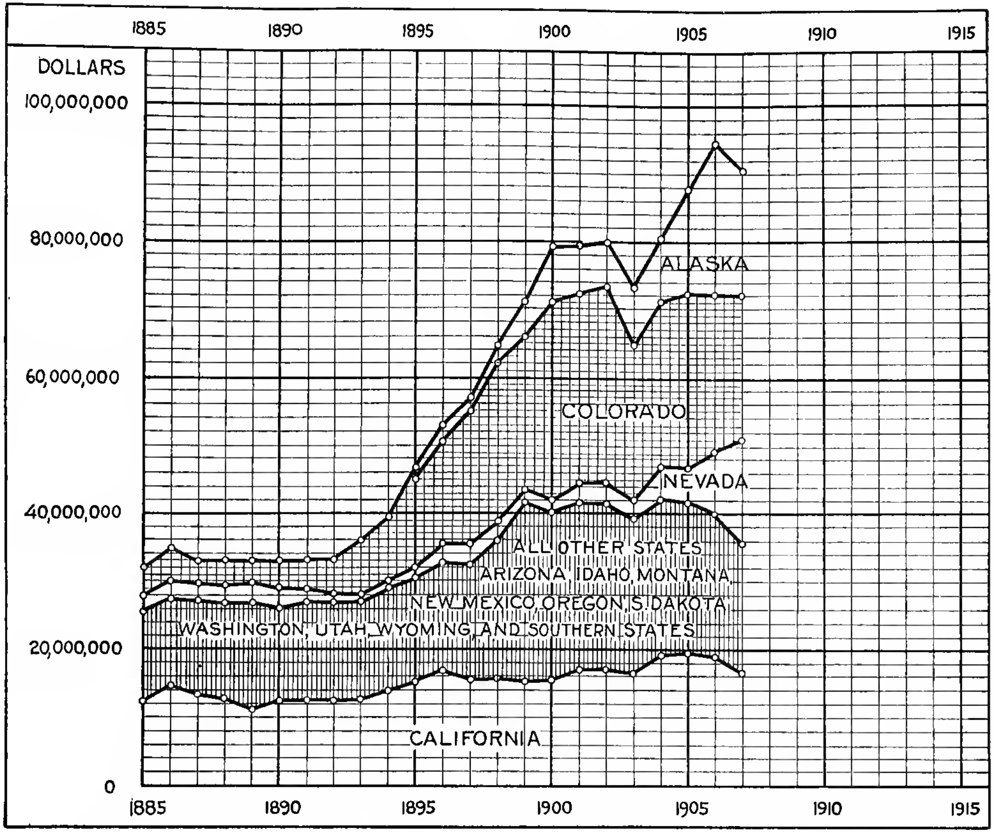
The rapid increase in the annual production of gold of the world is a feature which has been the subject of much discussion in its relation to the monetary systems and financial affairs generally. The facts are best brought out in the accompanying diagram. California and Australia in the early fifties brought the production rapidly to $180,000,000 from about $10,000,000 in 1830. The output in the earlier part of the century was largely derived from Russia. The gradual decay of placer mining in California and Australia reduced the yield for the world to nearly $100,000,000 about 1886. In the period from 1885 to 1890 numerous discoveries in South Africa, in Western Australia, and in Colorado changed the aspect of the industry.

The cyanide process, which gave better extraction at reduced cost, was introduced about this time. In South Africa especially this process has proved of the utmost importance. A little later discoveries were made in Alaska, Nevada, the Canadian Yukon, Mexico, Rhodesia, and West Africa, notwithstanding the assertion made by many that no further important supplies of gold were likely to be found.

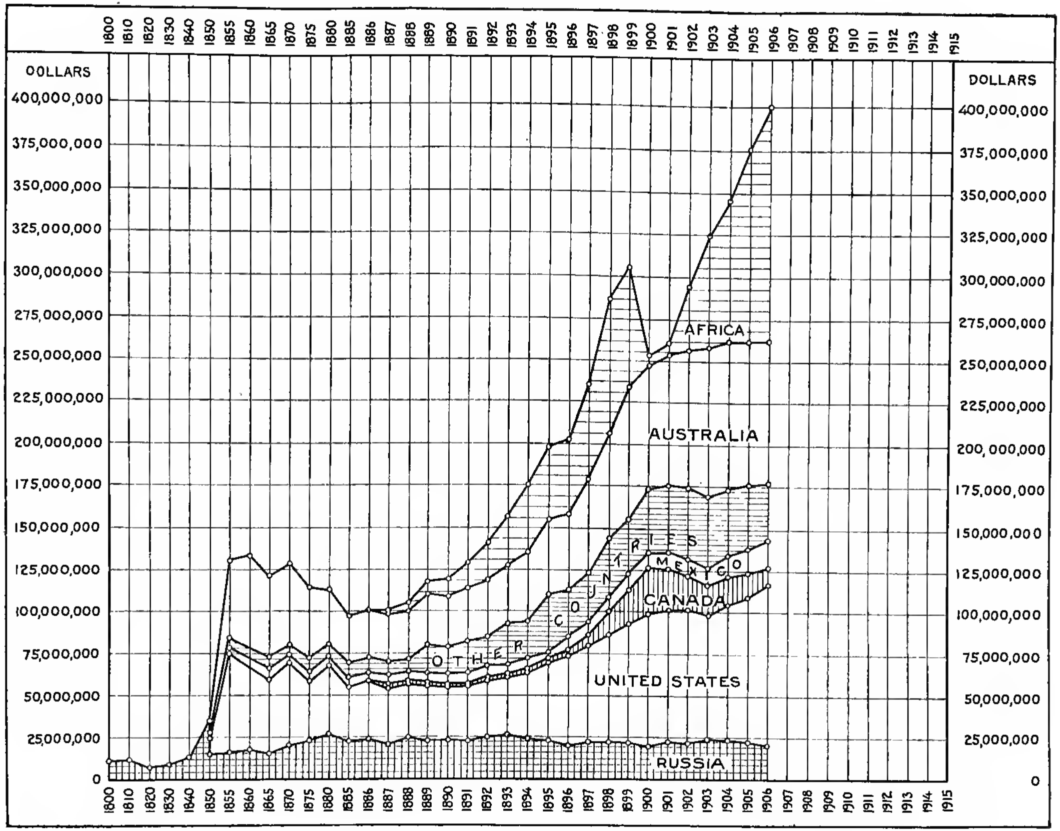
Thus, since 1887 the production of the world has been trending upward, except for the temporary decline due to the Boer war, and in 1907 was about $412,000,000. It will be observed that Africa now (1907) contributes about $151,000,000, or one-third of the world's production, and of the African output about $133,000,000 comes from a small district in the Transvaal.

Barring new and unexpected discoveries it is believed that the world's production will not increase hereafter at the recent rapid rate of advance. It is believed that the maximum production has nearly been reached in the Transvaal, although the present output can be maintained for a long time, probably for more than thirty years. The output of Australia from present indications is more apt to decline than to increase.

As indicated by the diagram, the production of Russia forms a solid and constant substratum on the permanence of which it is fair to rely. A continued increase in the United States is scarcely to be expected, although the recent history of gold mining in Nevada



THE PRODUCTION OF GOLD OF THE UNITED STATES AND OF THE PRINCIPAL STATES AND TERRITORIES FROM 1885 TO 1907.



THE PRODUCTION OF GOLD OF THE WORLD AND OF THE PRINCIPAL COUNTRIES FROM 1800 TO 1906.

(After E. Biedermann.)

shows what unsuspected riches may lie for decades within easy reach. It is true that there are large unprospected territories in South America which with developing lines of communication may produce much gold, but on the whole the probabilities of the immediate future are rather in favor of maintenance of the present level of output than of a further sensational advance.

RESOURCES OF THE UNITED STATES.

The diagram shows that the production of the United States can, for present purposes, be divided into five parts. In 1907 Colorado, Alaska, California, and Nevada in the rank indicated contributed each from $15,000,000 to $20,000,000 to the total output. The remaining fifth part, approximately $19,000,000, came from Utah, South Dakota, Montana, Arizona, Idaho, and Oregon, the amount from the remaining States (southern Appalachian region, New Mexico, Washington, and Wyoming) being negligible.

IDAHO AND OREGON.

Great constancy has been shown by Idaho and Oregon in their gold output, which for each State generally is below $2,000,000 per annum and may be expected to continue on the same basis for many years to come. The product is from placers and gold-quartz veins.

SOUTH DAKOTA.

In South Dakota the output has varied since 1889 from $3,000,000 to $7,000,000. Of this about $5,000,000 is derived from the Homestake mine, the most productive gold mine in the United States. The total yield of this mine approaches $60,000,000. A large tonnage of low-grade ore (about 1,400,000 tons per annum) is treated in a mill with 1,000 stamps. The deposit, as far as known, does not approach exhaustion; the shafts have not attained great depth. The blanket deposits in limestone may be exhausted at an earlier date than the Homestake, though the reserves appear to be fairly large. It is likely that South Dakota will be able to maintain its production for a long time.

ARIZONA.

Arizona has for many years supplied from $1,000,000 to $3,000,000, which is derived about equally from the copper ores of United Verde, Globe, and Bisbee on one hand, and the gold-quartz mines of Yavapai, Mohave, and Yuma counties on the other hand. From neither source is much falling off to be expected for the next ten years; a moderate increase is more probable.

MONTANA.

Montana has long maintained a steady gold production ranging from $3,000,000 to $4,000,000. For some years $1,000,000 has been derived from the Butte copper ores, and an equal amount from cyaniding the quartzose ores of Fergus County. The latter supply, however, has recently shown a sharp decline. The balance of the

State total has come from a great number of small gold and silver mines in several counties. It is not likely that the production of Montana in the near future will sink below $3,000,000.

CALIFORNIA.

The California production is notable for its constancy. Since 1885 the State has annually supplied from $12,000,000 to $19,000,000 in gold. The rise noted in the diagram during the last few years is largely due to the development of the dredging industry. In 1907 the State produced $16,900,000, which, disregarding some minor sources, may be divided as follows: Quartz mines, $9,400,000; copper mines, $350,000; placer mines, $6,800,000. The production from quartz mines has of late decreased, but it may be relied upon to continue, with fluctuations, for a long period. There are few very large mines, but there are many which have shown ability to maintain moderate production for many years past. Few of the mines have ore developed for more than two or three years, and even approximate figures as to future reserves are out of the question. On the other hand, a long-continued and steady output gives assurance of a continuance for a long period of years, with probable ultimate diminution. The gold from copper ores will increase, and may in a few years reach $1,000,000.

The placer-mining industry of California presents some interesting features. For many years the production from this source gradually decreased. This was largely due to the prohibition of hydraulic mining in the drainage areas of Feather, Bear, Yuba, and American rivers on account of the damage done to farming lands and to the harbor of San Francisco.

In the last ten years gold dredging has been developed to a high degree in consequence of the improvements in dredge construction and of the discovery that a large area near the mouths of the rivers flowing from the gold-bearing region of the Sierra Nevada is available for such mining. The output from the dredges in 1907 was somewhat over $5,000,000. Very sanguine predictions have been made as to the amount of land available for dredging in California and in the Rocky Mountain States, and to some degree they are justified. The fact remains, however, that the production of the Rocky Mountain States from dredging is as yet very small (about $300,000 in 1907), and it is believed that there are no extensive areas which at all compare with those at the base of the Sierra Nevada. It is estimated by the most competent authorities that the known dredging lands in the great valley of California amount to 18,000 acres. If an average depth of 45 feet, corresponding to 72,600 cubic yards of gravel per acre, and an average content of 12 cents per cubic yard, or $8,712 per acre, be assumed, then 18,000 acres would ultimately yield $156,800,000. Up to 1905 about 700 acres had been worked. This crude estimate may be considerably off the mark, but it serves to show that a large amount of gold is contained in the dredging lands, and that the industry will be of great importance for the next quarter century at least. The total dredge production of California since 1900 is about $18,000,000.

It has been stated that the production of the placer mines, outside of the dredges, has receded pretty steadily for many years, and that this is due to the practical prohibition of hydraulic mining in the basins of the principal rivers draining into the great valley. The gold reserves in these gravels are undoubtedly very large. Were these mines allowed to operate, several million dollars per annum could undoubtedly be added to the California production. Estimates by the United States engineer officers indicate that in the basins of the Yuba, American, and Bear rivers 1,500,000,000 cubic yards of gold-bearing gravel would ultimately be available by expensive development work, consisting in tunnels, ditches, etc., the amount at present available being about 500,000,000 yards. Adding to this estimate 100,000,000 cubic yards for the Feather River and the southern rivers draining into the San Joaquin, we would have 1,600,000,000 cubic yards, much of which is poor, but which may be assumed to average 6 cents per cubic yard.

According to this rough estimate nearly $100,000,000 in gold would be available if the hydraulic mines of the central gold region were permitted to work. Siskiyou and Trinity counties now yield $600,000 per annum from their hydraulic mines. The extent of the reserves in these counties is less well known, but they are believed to be large.

No State or Territory (except Alaska) compares with California as to the probable extent of gold reserves. There is reason to believe that California can maintain a production of $15,000,000 per annum for the next fifty years, and that then it probably would not be exhausted. Ultimately, of course, the gold reserves would become smaller, as has been the experience of the European countries in which gold mining once flourished. Eventually the gravels will be worked out, the dredging ground exhausted, the quartz mines impoverished or difficult to work on account of increased expense at depth. But this is looking far into the future. What the accompanying industrial conditions will then be is beyond our ken.

ALASKA.[a]

Though recently discovered, the mineral resources of Alaska have proved to be enormous. The total production of gold has risen rapidly and almost continuously since 1890. It reached $21,400,000 in 1906, but fell to $18,500,000 in 1907, and may decline somewhat further in 1908. This recession is, however, only temporary, for it is believed that the resources in placer gold are very large. The total gold output of Alaska since 1880 is about $122,000,000. Of this about $25,000,000 was produced from quartz mines in southeastern Alaska, which annually yield about $3,000,000. The Treadwell Island group of mines is the principal factor, with an ore production of 1,400,000 tons per annun and a recovery of about $2.50 per ton. The deposit can be compared only to that of the Homestake mine in South Dakota, and, so far as known, the ore body shows no contraction or serious diminution of tenor in depth. The greatest depth now attained is 1,650 feet. Probably no obstacles to mining at far greater depths will be encountered, and the present production seems assured for many years. There are other important quartz mines in process of development.

[a] A more detailed report on the Territory will be contributed by Mr. A. H. Brooks, of the Alaska division of the U. S. Geological Survey.

The placer fields of Alaska are chiefly in the Yukon basin and in Seward Peninsula. Mr. A. H. Brooks has shown that in the latter region the gravels contain a total of about $300,000,000. There is probably as much in the Tanana (Fairbanks) and Yukon basins and the largest part of this will probably be extracted by dredging. With better communications and with the development of technical methods, gravels of lower grade can be worked, although the lowest grade of material possible to handle must remain very much higher than for corresponding gravels in California. While in the latter State 10 cents per cubic yard will yield a profit, 50 cents will probably be the lowest limit for some time to come in Alaska, where steam thawing must be resorted to as a rule.

The copper deposits will add a certain, though not very large, amount to the gold production and it is not impossible that workable gold-quartz mines will be discovered in Seward Peninsula and on the Yukon.

As far as visible supplies are concerned Alaska stands easily first in the United States and will yield a large annual production of gold for a long period of years.

COLORADO.

Until 1892 Colorado was of comparatively small importance as a gold producer. From three to four million dollars were contributed with great regularity from the Gilpin-Clear Creek field and the San Juan region. The former field continues its production steadily with few changes; the depth attained is comparatively small and a continued yield of about $2,000,000 may be expected for an indefinite time. The San Juan region came into prominence some fifteen years ago with the development of the Telluride, Ouray, and Silverton mines and now yields annually $5,000,000 to $6,000,000. Some mines bid fair to continue for many years; others show signs of exhaustion, but the region has great possibilities and a long-continued production may be expected. In most cases reserves of "developed" or "probable" ore are not large. One prominent gold mine in this region now has reserves for two years in sight; but few have more and many have less.

The unexpected discovery and development of the Cripple Creek district in 1890 brought Colorado to the front as a gold-producing State and rapidly increased the State's output from an average of $4,000,000 to nearly $29,000,000 in 1900. In 1907 the gold production of Colorado was about $21,000,000. The new district proved extremely rich, but the largest ore bodies have now been worked out down to the depth of the lowest drainage tunnel. The quantity of ore above that tunnel has been enormous. Including 1907, Cripple Creek has produced $179,000,000. The maximum production of $18,000,000 was reached in 1900. In 1907 the output was $11,000,000. The future of Cripple Creek is largely dependent upon the character of the veins below the present tunnel level. A new tunnel 700 feet below the present drainage level is now being driven, but it will be at least two years before it will have reached the producing area. It is believed that the deposits will be less rich at greater depths, but the tunnel is likely to open many important ore bodies and its completion should be followed by an increase in the output, which may be maintained for many years. But it should be steadily borne in mind that this is only a probability. We know little about the conditions or the size of the ore shoots below the bottoms of the present shafts.

The conditions in Colorado are very different from those in California and Alaska. There are few extensive gravel beds which may be confidently predicted to yield millions of dollars. Basing an opinion as to the output of the future simply on the records of the past, one may say that the State will probably be able to maintain a production of $15,000,000 to $18,000,000 for a long period, and that the ultimate exhaustion of its lode mines is probably far distant.

NEVADA.

The gold-mining industry of Nevada has been characterized by sudden outbursts of high production followed by periods of depression. The bonanzas of gold and silver ores of the Comstock, Eureka, Tuscarora, and Pioche in the seventies were rapidly exhausted; then followed two decades from 1883 to 1903 of small gold production ranging from $1,000,000 up toward $4,000,000. The discovery of Tonopah and Goldfield brought another sudden rise in production, and in 1907 it attained $15,000,000, of which $11,000,000 was derived from the two new gold camps. The State has been very extensively prospected during the last eight years, and many new camps have been discovered, which, with improvement of methods and communications, will add their quota to its output.

To this State applies in a still higher degree what has been said about Colorado. The known reserves of ore are generally small, while their grade is high. One important mining corporation states in its report that it has reserves of about $8,000,000 in value, but this is exceptional. Other mines now producing will probably be exhausted in a short time. On the whole, however, it is likely that the aggregate output from the many mining camps already discovered will be sufficient to keep the production of the next ten years at least close to the $10,000,000 mark.

The copper mines of Ely will soon afford a steady yield of $300,000 to $500,000 per annum in gold as a by-product. Discoveries of deposits of great importance are always possible in Nevada.

CONCLUSIONS.

In the preceding paragraphs it has been shown that the reserves in gold of the United States are great, but that they can not be appraised with anything approaching exactness. Only in case of the placers is a rough estimate possible. It has been shown that the resources in placer gold are chiefly in Alaska and California. Based on present methods of working and present wages the recoverable amount of gold in these placers would perhaps approximate $1,000,000,000. The other States have also resources in placer gold, but they are of importance only in Montana, Idaho, and Oregon, and even in these States they are small compared to Alaska and California.

The placer gold won in the United States in 1907 amounted to about $24,000,000, and it is believed that this quantity can be supplied for a long succession of years. Ultimately the placers will be exhausted.

The amount of gold derived from copper ores in 1907 was only about $5,500,000, but this represents a stable and even increasing quantity which is to be relied upon at least for the next quarter century and most likely much longer. The gold derived from lead ores is much less (only about $2,100,000), and will probably slowly decrease for the next ten or twenty years.

From quartzose gold and silver ores $55,000,000 was recovered in 1907. No calculation can be made as to total reserves available, and the figures, could they be collected, would be of little use. Mines will be exhausted, but new ones are coming in. Ore shoots are worked out, but others are found. Most of the mining districts have as yet attained only a very moderate depth, and it may be said that the resources of siliceous gold ores are very far from being exhausted. Just how long they will last nobody can tell. In a general way ore deposits are more likely to decrease than increase in richness as depth is attained, and at the same time the operating costs are likely to become higher. It would seem that this ultimate decline is rather far off at the present time. Certain parts of the western country, particularly Nevada, Washington, and Idaho, still suffer from inadequate railroad communication, and each new line as a rule leads to the opening of a number of deposits which previously were unprofitable.

New discoveries are always possible and in some regions are probable. Methods of working are steadily improved.

Unless very important new discoveries are made it is thought unlikely that the production of gold in the United States will rise much above $110,000,000. Nor is it likely that it will sink below $60,000,000 within a long period of years.

The gold-bearing gravels and the dredging lands of California and other Cordilleran States have long ago passed into private hands. Only in Alaska are there any considerable amounts of such public lands left. It is believed that it would be in the highest degree inadvisable to withdraw from location any part of the placer lands of the public domain.

Regarding lode mines it must be remembered that land classed as mineral and part of the public domain may or may not be valuable. The value can, as a rule, be esablished only by expensive prospecting operations. To withdraw such mineral lands or to put a royalty on the product would be unwise.

WASTE.

There is comparatively little waste in the mining of gold ores. In the concentration of base ores the loss of gold is large, probably 30 per cent, but there is a relatively small amount of gold involved. In the usual combined process of amalgamation and concentration followed by cyaniding or in chlorination the loss is small; the recovery is generally about 90 per cent. In the recovery by smelting the loss of gold is extremely small and practically all of it is collected in lead or in copper matte. In electrolytic refining of copper and lead the loss is negligible.

At the same time it would be advisable to make storage of mill tailings compulsory. The reworking is sometimes profitable and can be done at little expense.

Much has been said about the loss in placer mining and in hasty operations in rich ground, as in Alaska; this is undoubtedly heavy, as attested by the repeated working of such ground. Even in better constructed plants there is some loss of fine gold, but the recovery is probably 95 per cent. In plants of the best kind, for instance hydraulic installations with undercurrents or dredges with the most improved appliances, the recovery may be considerably higher. It should be added, however, that few exact data concerning these losses are available.

CONSUMPTION.

The consumption of gold in the United States approximately equals the production; at least this appears to be true for the last thirty-five years.

In 1906, according to the Director of the Mint, the quantity of gold used in the arts, exclusive of gold coin and old material, had a value of about $29,000,000. (Total amount used in the arts, $39,000,000.) The quantity used has doubled since 1900. In 1906 gold was coined to the amount of about $79,000,000.[a] The total gold used for coinage and the arts in the United States in 1906 had thus a value of $108,000,000, or $14,000,000 more than the domestic product. The records show that a balance of $109,000,000 was imported during the same year, so that for 1906 $203,000,000 would represent the consumption of gold in the United States. The amount imported in 1907 was, however, unusually large.

For the period 1901–1905, according to Mr. Biedermann's[b] figures, the addition to the gold stock of the United States was $412,000,000, and this figure is $8,000,000 less than the domestic production for the five years. According to this the United States retained practically all of the gold produced within its territory for this time.

The total metallic stock of gold held in the United States on December 31, 1906, was, according to the estimate of the Director of the Mint, about $1,600,000,000. The production of the United States since 1873 is $1,650,000,000.

The total stock of gold coins in the world in 1905 was $8,050,000,000. Adding to this $2,000,000,000 as the probable amount used in the arts, we have a total of $10,000,000,000. Against this the total gold production of the world since 1860, according to the Director of the Mint, is $7,652,000,000.

The gold production of the world for the five-year period, 1901–1905, amounts to about $1,688,000,000.[c] This has ultimately been divided between the nations as follows: United States, $412,000,000; France, $378,000,000; Germany, $242,000,000; India, $177,000,000; Great Britain and Austria, each $112,000,000.

The flow of gold to India and Egypt has often been emphasized in the press. No doubt such importations are manufactured into jewelry or are hoarded and are permanently lost to commerce and industry. The above figures will show, however, that such hoarding has not caused the great demand for gold during recent years. The

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[a] Probably $6,000,000 of this consisted of mutilated domestic coins and scrap.

[b] Biedermann, E., Die Statistik der Edelmetalle, etc.: Zeitschr. Berg, Hütten u. Salinened wesen, Bd. 56, Heft 1, Berlin, 1908.

[c] Biedermann, E., op. cit.

real cause is the heavy absorption of the metal by the commercial nations in order to fortify their monetary position. The introduction of the gold standard has forced those great nations to create large gold reserves. This process has been going on for the last twenty years, but from now on the demand for gold for this purpose will probably slacken.

SILVER.

PRODUCTION OF THE UNITED STATES.

The silver production of the United States became of importance about 1860 and increased rapidly up to 1892, when it attained 63,500,000 fine ounces. The decline in the price had begun in 1875, and in the year of maximum output the price had fallen to 88 cents per fine ounce. Since 1892 the yield of silver has remained practically constant, averaging about 55,000,000 ounces. In 1907 it was 56,500,000 ounces, but the present year will witness a considerable decline. The lowest price of silver was about 47 cents, in 1902. The price rose to 70 cents in 1907, but has again declined to 50 cents, in October, 1908. The general result has been that a great number of mines which extracted silver ores have closed down, but the compensating factor that an increasing quantity has been obtained as a by-product from lead and copper ores has kept the output steady. The lower line in the diagram shows the course of the production of the metal in the United States.

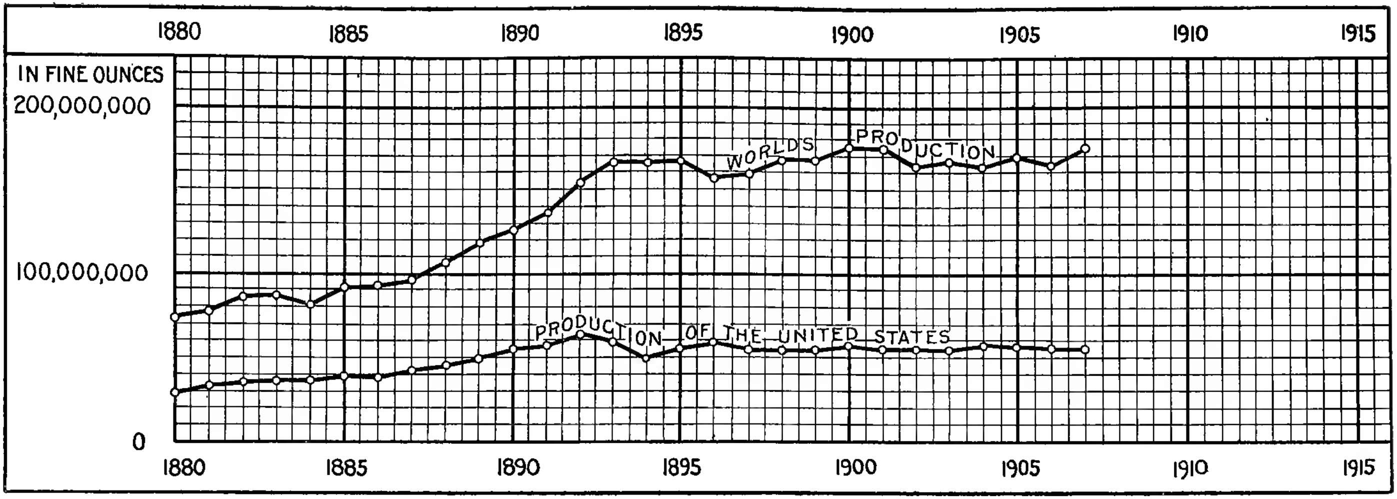
PRODUCTION OF THE WORLD.

The world's production of silver was 92,000,000 ounces in 1885, and about 178,000,000 ounces in 1907. The upper line in the diagram represents the world's production in the same time, and it well illustrates the constancy of the supply. The United States and Mexico are the most important contributors to the production of the world, the supply from each source being from 55,000,000 to 65,000,000 ounces. The rehabilitation of the mining industry of Mexico, which has taken place in the last twenty years, has gradually increased its output to more than double that of 1885. The remaining third of the world's production is mainly derived from New South Wales, Germany, Peru, and Bolivia. In many countries the output of silver is receding, owing to low price and difficulty of competing with the United States. To offset this, the silver output of Canada has lately been increasing at a rapid rate, and in 1907 attained nearly 20,000,000 ounces.

RESOURCES OF THE UNITED STATES.

The silver-producing States had in 1907 the following rank: Colorado, Montana, and Utah, each producing slightly over 11,000,000 fine ounces; Nevada and Idaho, each yielding about 8,000,000 ounces; Arizona, 3,000,000 ounces; and California, 1,500,000 ounces. None of the remaining States produced over 600,000 ounces.

An analysis of the statistics of 1906 is published in Bulletin 340 of the United States Geological Survey. From this it appears that the total output, disregarding the small amount of silver obtained from placer gold, was derived as follows: From lead, copper, and zinc ores, 40,100,000 fine ounces; from quartzose gold and silver ores,



THE PRODUCTION OF SILVER OF THE WORLD AND OF THE UNITED STATES FROM 1880 TO 1907 (IN FINE OUNCES).

16,500,000 ounces. A large proportion of the base-metal ores contained only a small amount of silver, which might be properly regarded as a by-product. Quartzose gold ores also contain silver which is recovered as a by-product and from this source 4,000,000 ounces were obtained in 1906, making one-quarter of the total from quartzite ores.

Looking at the question from another standpoint, it was found that from ores which carry predominating silver values, and which thus may be classed as silver ores, 19,500,000 fine ounces of silver were obtained. This is somewhat more than one-third of the total output of 56,500,000 ounces. It must be taken into consideration, however, that at least one-half of these ores could be profitably mined only because other metals besides silver were present. Only 1,500,000 ounces were obtained from ores containing no other recoverable metals.

From these data the present small importance of silver mining as a distinct and separate industry is clearly perceived. The pure silver ores are not scarce, but at the present price of the metal they can not be profitably treated unless containing at least about 20 ounces per ton. The lead ores of the Rocky Mountain region are as a rule richer in silver than the copper ores. In the lead ores of the Mississippi Valley silver is either absent or contained in extremely small quantities. Should the quantity of lead ores mined in Colorado and Utah gradually diminish, which seems probable, a corresponding diminution of the silver supply would follow. On the other hand, copper will probably for many years be mined on an increasing scale, and although the copper ores are poor in silver, the great tonnage handled will add much silver to our annual output and compensate for the possible loss from the decrease in the supply of lead ores. The zinc ores do not contain much silver; those of southwestern Missouri are free from silver, and the Rocky Mountain ores rarely contain more than a few ounces per ton.

From all this it is evident that the present supply of silver is assured as long as the mining of lead and copper ores, as well as of quartzose gold ores, continues on the present scale. Should there ever be a scarcity of silver, with accompanying rising price, the Rocky Mountain region beyond doubt contains a large supply of quartzose low-grade silver ores which could be profitably extracted with silver above 70 or 80 cents per ounce.

CONSUMPTION.

The United States consumes only a part of the silver produced. The domestic consumption is divided between coinage and industrial uses for the manufactures and arts. The demands for the latter use have doubled since 1898, and at present the amount consumed is 20,000,000 ounces, of which about 4,000,000 ounces represent old material remelted. For coinage the mints consume variable amounts ranging, during the last ten years, from 4,500,000 ounces to 23,000,000 ounces. In 1906, 7,700,000 fine ounces were coined. The total domestic consumption of the yearly product of the mines may be placed at 25,000,000 ounces. The remainder, about 32,000,000 ounces, is exported As is well known, the larger part of the export is taken by India and China. The demand by India is in the aggregate an enormous sum and is inereasing at a rapid rate. For 1906–7 the total imports of silver by India were over 118,000,000 ounces, an inerease of 34,000,000 ounces over 1905–6. On the other hand, the generally mueh smaller demand from China fell off, and during 1906 that eountry aetually exported silver. The larger part of the silver whieh goes to India is, as well known, permanently lost to our industrial world by hoarding. Sinee the Indian government has sueeeeded in establishing the permanent value of the rupee at 16 penee (on basis of 1:21.85) it is likely that the deeline in priee of silver will be eheeked, but the supply appears to be so great that a vigorous reeovery ean hardly be expeeted.

COPPER.[a]

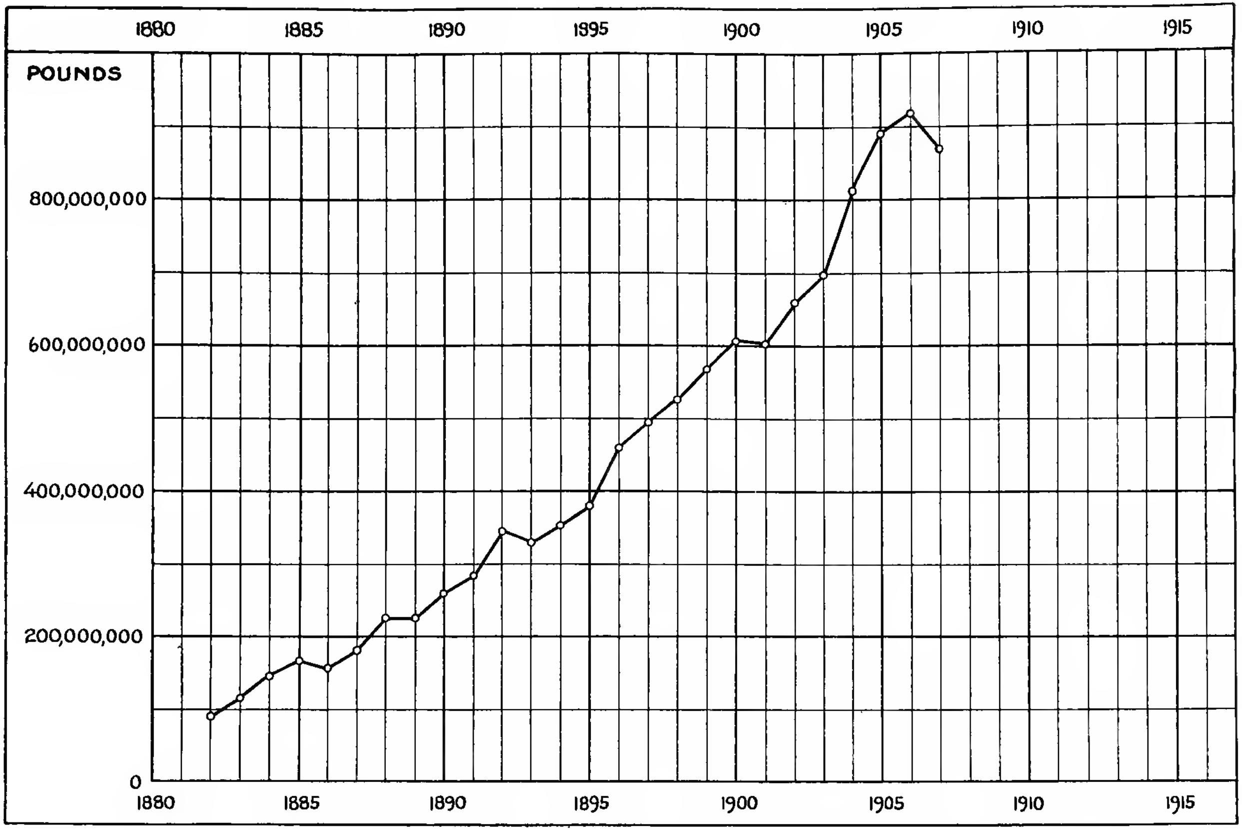
PRODUCTION OF THE UNITED STATES.

The eopper-mining industry of the United States has developed at a rapid rate. In 1888 the produetion was 226,000,000 pounds of the metal. After eight years, in 1896, it had doubled. After ten years again, in 1906, it had nearly quadrupled, attaining almost 918,000,000 pounds. Reaetionary tendeneies developed in 1907 and 1908, and the output of the latter year will probably be about 860,000,000 pounds. It is impossible to aeeurately foreeast the final eharaeter of the eurve of produetion, but if we draw a straight line from the point on the diagram representing the produetion of 1883 to that of 1908, we shall with some probability have the trend of the produetion for future years. It is altogether improbable that the inerease will eontinue at an inereasing rate; more likely the rate will gradually diminish; a straight line will probably express its trend for the next ten years, at least. On this basis the produetion would be about 900,000,000 pounds in 1910, and 1,160,000,000 pounds in 1920. The following table will give a good idea of the growth of the industry sinee 1845. It shows that the rate of inerease during the present deeade is eonsiderably smaller than it was during the deeades 1881–1890 and 1891–1900:

Magnitude and growth of copper production in the United States from 1845 to 1907, inclusive.

Year.	Production.	Increase.		Average annual increase by decades.	
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
1845	224,000				
1846	336,000	112,000	50.0		
1847	672,000	336,000	100.0		
1848	1,122,000	450,000	67.0	242,400	50.0
1849	1,568,000	426,000	40.0		
1850	1,456,000	[b] 112,000	[b] 7.1		
1851	2,016,000	560,000	23.1		
1852	2,464,000	448,000	22.2		
1853	4,480,000	2,016,000	81.8		
1854	4,990,000	510,000	12.5		
1855	6,720,000	1,730,000	33.3		
1856	8,960,000	2,240,000	33.3	1,467,200	27.0
1857	10,752,000	1,792,000	20.0		
1858	12,320,000	1,568,000	14.6		
1859	14,112,000	1,792,000	14.5		
1860	16,128,000	2,016,000	14.3		

[a] Prepared with the assistance of Mr. L. C. Graton, of the U. S. Geological Survey.
[b] Decrease.



THE PRODUCTION OF COPPER IN THE UNITED STATES FROM 1882 TO 1907 (IN POUNDS).

Magnitude and growth of copper production in the United States, etc.—Cont'd.

Year.	Production.	Increase.		Average annual increase by decades.	
	Pounds.	*Pounds.*	*Per cent.*	*Pounds.*	*Per cent.*
1861	16,800,000	672,000	4.1		
1862	21,160,000	4,360,000	20.0		
1863	19,040,000	a 2,120,000	a 5.5		
1864	17,920,000	a 1,120,000	a 5.9		
1865	19,040,000	1,120,000	6.3		
1866	19,936,000	896,000	4.7	1,209,600	6.1
1867	22,400,000	2,464,000	12.3		
1868	25,984,000	3,584,000	16.0		
1869	28,000,000	2,016,000	7.7		
1870	28,224,000	224,000	1.0		
1871	29,120,000	896,000	3.2		
1872	28,000,000	a 1,120,000	a 3.8		
1873	34,720,000	6,720,000	24.0		
1874	39,200,000	4,480,000	12.9		
1875	40,320,000	1,120,000	2.9		
1876	42,560,000	2,240,000	5.6	3,225,600	7.2
1877	47,040,000	4,480,000	10.5		
1878	48,160,000	1,120,000	2.4		
1879	51,520,000	3,360,000	7.0		
1880	60,480,000	8,960,000	17.4		
1881	71,680,000	11,200,000	18.6		
1882	90,646,232	8,966,232	12.5		
1883	115,526,053	24,886,221	27.4		
1884	144,946,653	29,420,600	25.5		
1885	165,875,766	20,929,113	14.4		
1886	156,735,381	a 9,140,385	a 5.5	18,930,349	14.8
1887	180,920,524	24,185,143	15.4		
1888	226,361,466	45,440,942	25.1		
1889	226,775,962	414,496	.2		
1890	259,763,092	32,987,130	14.5		
1891	284,121,764	24,358,672	9.4		
1892	344,998,679	60,876,915	21.5		
1893	329,354,398	a 15,644,281	a 4.8		
1894	354,188,374	24,833,976	7.5		
1895	380,613,404	26,425,030	7.4		
1896	460,061,430	79,448,026	20.9	34,635,407	9.1
1897	494,078,274	34,016,844	7.4		
1898	526,512,987	32,434,713	6.6		
1899	568,666,921	42,153,934	8.0		
1900	606,117,166	37,450,245	6.6		
1901	602,072,519	a 4,044,647	a 0.7		
1902	659,508,644	57,436,125	9.5		
1903	698,044,517	38,535,873	5.8		
1904	812,537,267	114,492,750	16.4	37,554,189	5.5
1905	888,784,267	76,247,000	9.4		
1906	917,805,682	29,021,415	3.3		
1907	868,996,491	a 48,809,191	a 5.3		
Total production, 1845–1907	12,163,637,913				
Average annual increase, 1846–1907		13,880,213	15.0		
Average annual increase, 1846–1881		2,034,333	17.2		
Average annual increase, 1882–1907		30,282,201	9.9		

a Decrease.

PRODUCTION OF THE WORLD.

The world's production of copper has also increased rapidly, but not at the rate attained by the United States. From 274,000 metric tons in 1890 it has grown to 711,000 tons in 1907. To this amount the United States contributed, respectively, 118,000 and 386,000 metric tons. The paramount importance of this country is easily perceived.

The world's production, outside of that of the United States, increased as follows:

	Metric tons.
1890	156,000
1895	165,000
1897	182,000
1900	219,000
1905	297,000
1907	325,000

From this it will be seen that the increase was slow from 1890 to 1895, and that it then began to mount rapidly, doubling in the twelve years from 1895 to 1907.

No single country compares in importance with the United States. The supply from the Rio Tinto mines in Spain and Portugal is almost constant at 50,000 metric tons per annum; that of Germany and Chile likewise, with, respectively, 20,000 and 27,000 tons. Australia, Canada, Mexico, Japan, and Russia have shown rapid growth in the copper industry; among these Japan leads with an output of 49,000 metric tons in 1907. For the next few years increased production may confidently be expected from Canada, Mexico, and Russia. Copper deposits of enormous extent are reported to have been discovered in central Africa. Their product is not likely, however, to compete with other sources for five or seven years.

RESOURCES OF THE UNITED STATES.

For many years the bulk of the copper production has been divided between Michigan, Montana, and Arizona. In each of these States the increase has been rapid and continuous since 1880, but for a series of years, beginning with 1891, Montana far exceeded the other two States. In 1895, for instance, Montana produced 50 per cent; Michigan, 34 per cent; and Arizona, 12.6 per cent of the total output. During the last few years there has been a tendency to equalization, caused by the rapid advance of Arizona. In 1907, of a total of 869,000,000 pounds, Arizona yielded 257,000,000; Montana, 224,000,000; and Michigan, 219,000,000 pounds. Utah comes next with a production of 66,000,000 pounds. California yielded 34,000,000 pounds; Tennessee, 20,000,000 pounds; Colorado, 14,000,000 pounds; New Mexico and Idaho each, 10,000,000 pounds; Alaska, 7,000,000 pounds; Wyoming, 3,000,000 pounds; and Nevada, 2,000,000 pounds. These 12 States are the only ones which will have to be considered in more detail. The less important will first be disposed of.

COLORADO.

Colorado can be dismissed in a few words because the copper is largely recovered as a by-product from many mines with mixed ores, chiefly, in fact, from the Leadville mines. The State has no important copper mines and it is not likely that its production will exceed the figure of 1907, when special incentive to the recovery of this metal was given by abnormally high metal prices.

IDAHO.

Idaho has three copper districts of some importance—the Cœur d'Alene, the White Knob, and the Seven Devils. With copper prices at 13 cents the last two districts will probably not be able to attain a large yield. At present the greatest part of the production comes from the Snowstorm mine in the Cœur d'Alene district. With copper at 15 cents, or higher, the reserves of the State will be materially augmented and the present production could probably be increased.

WYOMING.

The State of Wyoming produces copper from the Encampment district, near the Colorado line. The deposits are fairly large and there is probably a considerable amount of low-grade ore in the district. Low-grade copper deposits are known to exist in Albany, Fremont, and Natrona counties. The State will never rank among the greatest producers in the country, but may be able to maintain a production of a few million pounds per annum.

NEW MEXICO.

New Mexico possesses large bodies of low-grade copper ores in the Burro Mountains and at Santa Rita. Exact figures can not be given, but with copper prices at 15 cents the Territory will probably be able to maintain its present output (10,000,000 pounds in 1907) for a long period of years. Many of the other mining districts, especially the Mogollon and the Organ, will continue to contribute to the total output. The copper-bearing sandstones of upper Carboniferous to Lower Cretaceous age are developed in New Mexico upon an enormous scale. They are present in the Zuni, the Nacimiento, the Mora, the Oscura, and many other ranges. Past experience has shown that with copper at 13, 15, or even 20 cents, these extensive deposits can not be profitably worked, except on a small scale for selected rich ores; but with prices above 20 cents they should come into the range of probable resources.

ALASKA.

The Territory of Alaska contains at least three copper districts of importance, the Kasaan Peninsula, Prince William Sound, and the Copper River region. From the first and second districts an output of 7,000,000 pounds was obtained in 1907. The deposits are irregular. The ores of the first district are of low grade but easily smelted. At copper prices of 13 cents the outlook is doubtful, but at a higher rate the peninsula may yield a considerable amount for a number of years. The deposits on Prince William Sound are considered promising, but are too little developed to allow a judgment as to future possibilities. Probably they will furnish a fair amount of copper. The Copper River deposits are likewise as yet in the prospect stage, but may in time develop into an important copper-mining district. The most promising property is at present the Bonanza mine, a large body of high-grade chalcocite ore. No data are as yet available as to its continuation in depth.

TENNESSEE.

At Ducktown, Tenn., the Tennessee Copper Company and the Ducktown Sulphur, Copper, and Iron Company are producing an aggregate amount of 18,000,000 to 20,000,000 pounds of copper per annum. The reserves of ore are believed to be sufficient for at least ten years. It is said that the former company has now developed and produced ore to the extent of 3,300,000 tons. About 389,000 tons of ore were mined by this company in 1907.

We now come to a consideration of the States which at present are of paramount importance in the production of copper. They are Michigan, Arizona, Montana, Utah, Nevada, and California.

MICHIGAN.

Michigan, which up to the present time has been the largest contributor of all the States to the total copper output of this country, began production in 1845 and has been steadily and increasingly productive ever since. The output in 1907 was over 219,000,000 pounds. The entire production has been drawn from the Lake Superior copper district of the northern peninsula, and the productive area is a belt 1 or 2 miles wide by about 70 miles long. Developments are more extensive than in any other copper district. The grade of the ores has steadily declined and now averages only about 1.1 per cent recovered. Costs of operations are extremely low, however, and the greater part of the present output can be maintained under the current copper market. The tonnage of ore that is reasonably assured is enormous and probably exceeds that in any other district; it is now being depleted at the rate of almost 10,000,000 tons annually. One company alone estimates 20,000,000 to 25,000,000 tons remaining in one lode (the "Calumet" conglomerate) in its ground that has been worked since the sixties of last century. Another lode (the Kearsarge) is being mined for 12 miles along its strike almost without break, and to depths on the incline ranging down to about 5,000 feet. A third very important lode (the Baltic) is being found much more extensive than formerly known, and, like the Kearsarge, promises to yield an enormous output before exhaustion. Two other lodes (the Osceola and Pewabic) are of much importance and may be safely counted on for large production for many years. Several of the smaller producing lodes will long continue to contribute to the State's supply, and some of the extensive development in the northern end of the district is likely to bring out important resources.

The conglomerate ores, which so far have yielded more than half the total output and are decidedly richer than the amygdaloid ores, will probably cease to be productive, at the present rate of working and under normal prices, at the end of fifteen years—twenty at most. But the amygdaloid ores, which are much more cheaply worked and in this way offset their lower yield, are able to maintain the district as one of the great copper regions of the world for many years to come. The deepest workings have now attained a vertical depth of practically one mile, and as the workings are extended farther down, the increasing cost of operation and the decreasing grade of ore will ultimately make mining unprofitable. While this condition seems not far in the future at certain local points, its effect on the general output of the district will, to judge from present tendencies, be felt at a very remote time.

Copper is known to occur for many miles beyond the southwestern end of the productive belt, but the development of important resources there is as yet problematical. It is probable that at best that section can achieve important output only under higher prices than can be reasonably expected for many years.

ARIZONA.

The foundation of the present production of Arizona, which in 1907 was about 257,000,000 pounds, was laid in 1873, when mining began in the Morenci district. Within a few years the Bisbee district became a producer and the ores of the old silver district at Globe became chiefly valuable for copper. Shortly afterward the United Verde mine at Jerome became an important producer. The production of these four districts increased steadily and rapidly, and in 1907 they produced jointly over 240,000,000 pounds, or more than the total yield of any other State. While there are a large number of other producing districts in the Territory, of which two or three are of decided promise, these four principal centers of production must be chiefly relied on for many years if Arizona is to maintain her output.

BISBEE.

The Bisbee district produced about 110,000,000 pounds in 1906, and practically all of it came from ores of relatively high grade. Most of the output was from secondary or enriched ores, and was produced at a cost low enough to maintain the district as an important producer with prices decidedly lower than at present. The principal companies are known to have good reserves blocked out, but figures as to tonnage and tenor are not available. There is a fair outlook for adding laterally to the productive area. The lowest workings are about 1,400 feet deep, and the primary or little-enriched sulphide ore of good grade encountered at that depth is an encouraging indication of possibilities.

MORENCI.

The high-grade ores of the Morenci district have been largely exhausted, and for a number of years the chief source of production has been the comparatively low-grade concentrating ores formed by secondary enrichment. The production in 1907 was about 63,000,000 pounds. A large tonnage is still doubtless available for extraction, but at a depth which only in a few places exceeds 400 feet the workable ores give way to the original pyritic deposits that are of too low grade to be profitably worked under any conditions that can at present be reasonably forecast. The ground that is possibly copper bearing has not yet been entirely prospected, and during the past three years of good prices the principal operators have conserved the better-grade ores. But it seems probable that the district has about reached its climax in annual output, and that a sustained period of low prices would cause the production to decline sharply.

At Bisbee and at Morenci the precious metals occurring with the copper are not sufficiently plentiful to have appreciable effect on conditions of production.

GLOBE.

The Globe ores likewise were formerly of high grade, but the district, which produced 35,000,000 pounds in 1907, is relying more and more on its medium and low grade ores. The bulk of the present output is from enriched ore. Lean pyritic ore has been reached at a depth of about 800 feet, but the secondary ore of workable grade has been developed in places to the present maximum depth of about 1,200 feet. There is reason to believe that some of the underlying sulphide ore may be profitably extracted, but as a source of important contribution to the copper supply this is very uncertain. Recently the Miami Copper Company has developed a very important low-grade deposit of the well-known type, consisting of disseminated secondary sulphides. The company estimates 4,200,000 tons of 2.9 per cent ore developed and 2,200,000 tons of probable ore in addition, with good prospect of increasing this tonnage. They estimate that in all probability a total of at least 250,000,000 pounds of copper can be taken from the mine as at present developed at a cost of 9 cents per pound. Production from this property is expected to begin in the near future. In the vicinity of Globe there is without doubt a large tonnage of ore, partly of good grade, not as yet altogether systematically developed. Promised improvement in local transportation and bettered metallurgical conditions resulting from increase of sulphide ores produced in the district will almost certainly be followed by increased production from this outlying territory, but the magnitude and persistence of this supply can not now be foretold.

JEROME.

The Jerome district, in Yavapai County, produced 33,000,000 pounds of copper in 1907. As in former years, nearly all this came from the United Verde mine. The ore body is a great lens of pyrite and chalcopyrite in schists and has been opened by workings to the 1,000-foot level, beyond which depth the ore is reported to continue. There is undoubtedly a large tonnage yet to be extracted above this level. Gold and silver are present to the extent of about 1.4 cents per pound of copper, and the copper percentage is high, the ore ranking with the Bisbee ores as the richest now mined on a large scale in the United States. Prospecting in the surrounding region has not as yet disclosed any other deposits of importance.

OTHER DISTRICTS.

At the Silver Bell district, in Pima County, important developments have been made and improvements are nearly completed to largely increase the production of 1907, which was over 5,000,000 pounds. Contact-metamorphic sulphide ores of both smelting and concentrating grade have been opened and the tonnage exposed is reported to be large. In the Mineral Creek district of Pinal County the Ray Consolidated Copper Company has opened a disseminated chalcocite body in porphyry, and estimates indicate that about 3,000,000 tons of about 2.4 per cent tenor have been already developed and can be profitably worked with copper selling at 12 cents. A large tonnage of low-grade garnet-chalcopyrite ore is reported as existing in the Saddle Mountain region, in Gila County, but it is not certain that it can be worked at the present metal market. A large quantity of low-grade ore consisting of copper minerals disseminated in sedimentary rocks is known in the Grand Canyon region, but development has been slight and no generally satisfactory method of reduction has yet been found for application at recent prices of copper.

These four regions have not yet been studied by members of the Geological Survey, and further definite information is not available.

A few million pounds of copper are produced annually in Arizona incidental to the recovery of precious metals. This will doubtless continue, and the probability is that the quantity will increase somewhat. While this source of supply will be relatively independent of the price of copper, it probably can never be of much importance.

The prospect of discovering new important copper fields in Arizona is perhaps brighter than in any other State or Territory.

MONTANA.

The importance of Montana as a copper-producing State began in 1880 with the advent of railroad transportation to Butte, the only large copper district of the State. Production increased with great rapidity, and in 1887 the district was the most productive in the world. It has held that rank almost steadily to the present time, as Montana led in the production of copper until 1907, when it was surpassed in this respect by Arizona. The production of the State in that year was about 224,000,000 pounds, nearly all of which was derived from Butte. The ore bodies of Butte are secondarily enriched portions of pyritic replacements and impregnations of zones of crushed granitic rock. In the early years the ores were of extremely high copper content and carried much silver. Now the greater part of the production is from rather low-grade concentrating ores, and the recovery from all ores is but little over 3 per cent copper. The yield of precious metals is more than 2 cents per pound of copper. The principal output is from a very small territory, and prospecting in the outlying ground during the last few years has failed, in most cases, to give encouraging results. A large tonnage of ore is undoubtedly still available for extraction, but lean pyritic material has been encountered in a number of places at about the same depth (the 1,600-foot level of certain mines) and most of the good ore bodies that occur at greater depths, down to 2,600 feet, are probably to be regarded as localizations of enrichment along certain easily permeable channels. The cost of producing copper is high and the output at the rate of 1905 and 1906, or even of 1907, probably can not be maintained for a long period on copper at 13 cents per pound.

UTAH.

The production of Utah has increased greatly during the last few years. In 1903 the output was approximately 30,000,000 pounds, while in 1906 it had attained 66,000,000 pounds, with prospect of still further increase. The Utah copper is mainly derived from the Bingham district, though smaller quantities are obtained from the Tintic and Frisco districts. All these ores yield also much gold and silver, and their extraction is therefore to a certain extent independent of the price of copper. A production of about 50,000,000 pounds could undoubtedly have been maintained for a series of years, as new reserves were constantly discovered. The recent discovery and utilization of the low-grade Bingham porphyry ores, probably the largest single body of copper ore known in the United States, will, however, advance Utah still further in the rank of the copper-producing States. The two largest companies which treat this ore estimate the aggregate reserves of ore blocked out or partially developed at 120,000,000 tons, which, provided that all of this ore can be extracted, should yield a very large quantity of copper, besides a considerable amount of gold and silver. The yield thus far is somewhat below 2 per cent copper. The copper can be produced cheaply, it is claimed at 8 cents per pound. The tonnage to be treated per day in the plants of the Utah Copper Company and the Boston Consolidated Copper Company is over 9,000 tons, or 3,150,000 tons per annum. At this rate the ores would last about thirty-eight years. In addition a large amount of ore of somewhat lower but probably workable grade is partly developed.

NEVADA.

Until recently Nevada was of little importance as a copper-producing State, but the development of the Ely and Mason Valley districts have materially changed the outlook. At Ely low-grade but enormously large copper deposits have been opened and will begin production in 1908. The three companies working at Ely, the Nevada Consolidated Copper Company, the Cumberland-Ely Mining Company, and the Giroux Consolidated Mines Company, report an aggregate of about 28,000,000 tons of developed and probable ore containing about 2 per cent copper with some gold and silver. The mills erected will have a total capacity of 4,500 tons per day, or 1,500,000 tons per annum. The proved reserves would therefore last about nineteen years. The total cost of mining and reduction will, it is believed, be low; it is claimed less than 10 cents per pound of copper. It is thought that the output of the Nevada Consolidated will be at the rate of 24,000,000 pounds per annum. In the Mason Valley district near Yerington important bodies of ore have also been opened and will probably soon contribute to the output of Nevada.

CALIFORNIA.

The copper production in California began in Calaveras County about forty years ago, but the industry there soon declined and it was not until 1897, when the Shasta County mines began copper production, that the output of this State became important. The production in 1907 was over 33,000,000 pounds.

SHASTA COUNTY.

The Shasta County copper region, which in 1907 produced about 28,000,000 pounds, embraces four districts within an area about 6 by 20 miles. Rich copper-silver ores were first worked at some of the mines, but these have been exhausted, and practically the whole output is at present derived by smelting massive pyritic ores, which yield on the average about 3.6 per cent copper and nearly 3 cents in gold and silver per pound of copper. The ore bodies are large replacement bodies, mostly in porphyry, and in most cases are flat-lying lenses; in a few cases the ore bodies are more nearly vertical. A very large tonnage is now blocked out and in process of extraction. One company has several million tons practically developed, and four other companies have proved up large reserves. One of the largest bodies has been practically worked out and the limits of most of the others are now known. Additional deposits may be discovered from time to time, for the region has not been thoroughly prospected, but the probability is that the best deposits existing are already known. Some of the mines probably have ore of too low grade to be continuously worked with profit under the current prices for copper, and others are dependent for present operation on the simultaneous production of sulphuric acid from the ores. Under favorable metal prices the production of the region is likely to increase rapidly and then after a number of years to decline sharply.

OTHER DISTRICTS.

The only other copper-producing district of any importance in California is in Calaveras County, where sulphide ore of good grade is found in schist. The production has varied greatly from year to year. In 1907 it was somewhat over 4,000,000 pounds. Details as to the probable future of this region are not available, but the outlook is generally considered good.

There is a long stretch of country in the western foothills of the Sierra Nevada where copper is known to occur mostly as lenticular sulphide bodies in schist or slate. Small production has been made from time to time. At most points developments are meager and the future is unknown, but there is reason to believe that with proper application of capital, improved transportation, and good copper prices, this district might make a considerable output. At the Dairy Farm mine, in Placer County, on this belt, a large body of sulphide ore has been blocked out and extraction will probably begin in the near future. The ore is not of high grade and its extension much beyond the ground thus far developed is not certain.

Small production comes from Inyo and San Bernardino counties, in the southern part of the State, but developments as yet do not warrant relying on that region for an important copper supply.

CONCLUSIONS.

The visible reserves of copper ore in the United States are much larger than those of lead ore. Moreover, they are very much larger now, at the maximum of production, than they have ever been before. And yet, upon perusing the preceding notes it is evident that few companies have reserves for as much as ten years and that only in one case are they believed to be sufficient for forty-five years. On its face this condition seems discouraging, at least when we compare it with the enormous reserves established in the investigation of the coal-mining industry. As has been explained in the general part of this discussion, copper deposits differ so completely in their occurrence from coal beds that known reserves like those of coal can not be expected. Each year will, however, surely find extensions of reserves added to those already discovered and large new deposits of low-grade copper ores will also undoubtedly be opened. These possibilities are well illustrated by the discovery within the last two years of a 7,000,000-ton ore body near the old camp of Globe, Ariz., which one might reasonably suppose to be well prospected.

All these data of available reserves are based on copper at about 13 cents per pound. A large part of them would prove unprofitable to extract should the value of the metal sink much below that figure. Should copper increase to 15 or 20 cents per pound the reserves of many mines would unquestionably be vastly increased. Should it go above 20 cents per pound, still more extensive reserves would be available in the cupriferous sandstones of the Southwest. These conclusions, again, are based on present methods of working and recovery. Should further great improvements be made in these processes the limits indicated by the prices might be materially altered.

The copper resources of the United States are believed to be large enough to respond for a number of years to a demand increasing at the rate of 30,000,000 pounds per annum. It is to be anticipated that should this demand continue for a long period the scarcity of ore would ultimately be felt and result in a rising price for the metal. This again would undoubtedly cause the substitution of other metals, like aluminum, for copper whenever possible.

All these considerations have left the foreign supply out of the question. If recent reports are correct, central Africa contains enough copper to supply the world for years to come.

The whole problem of the ores supply contains so many unknown quantities that a final and definite answer is impossible. In the last analysis, however, it comes down to the question whether it is better for a country to reserve its copper for the future, when its value is an unknown quantity, or extract the ore at as rapid a rate as possible when profit is assured. It is believed that the latter method is the best, if at the same time avoidable waste is prevented.

CONSUMPTION.

Only a part of the copper produced is consumed in the United States; exports have been maintained on an increasing scale for the last thirty years. At the present time some, but not much, copper ore is imported to our smelters. On the other hand, there is a large output of foreign raw copper which is refined in the United States. In 1907 the total foreign copper refined in this country amounted to 248,000,000 pounds, or one-third of the domestic production of refined new copper, which for the same year was 784,000,000 pounds.

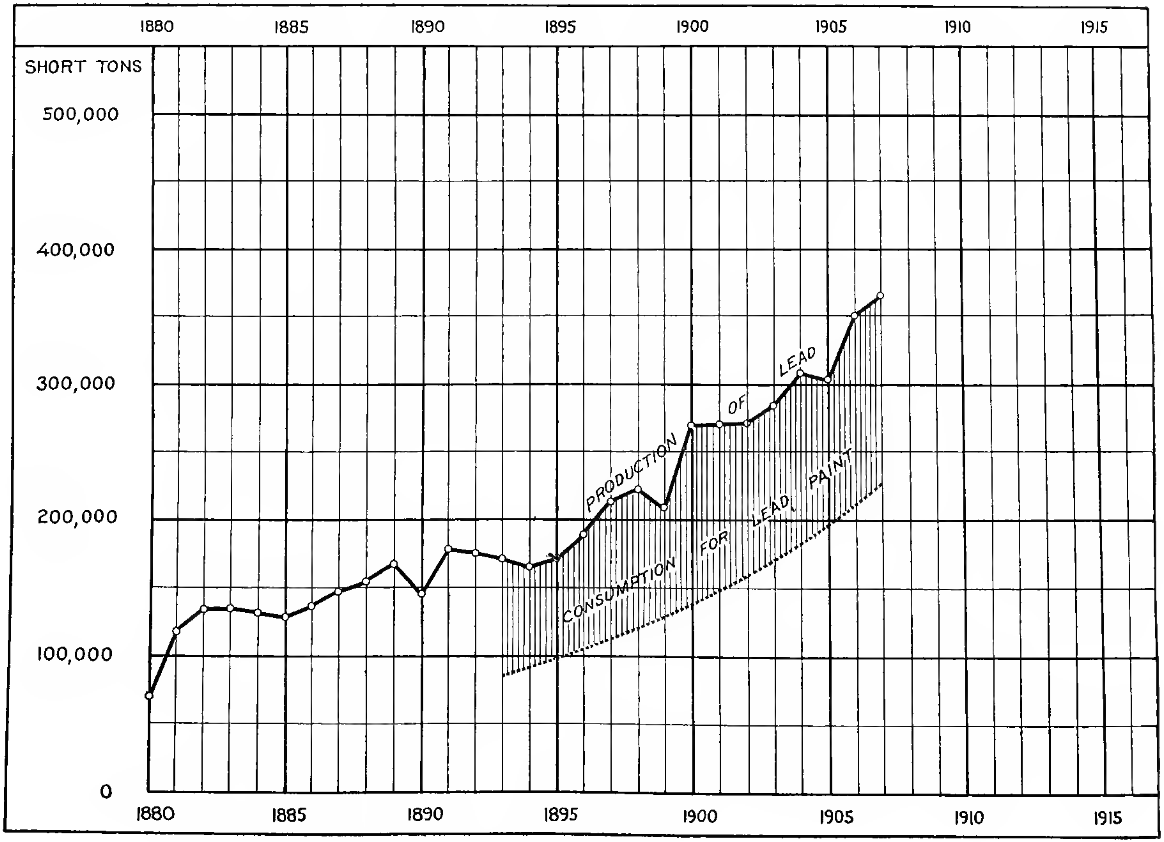
There is no duty on copper or copper ores to interfere with the natural operations of supply and demand. The copper industry has developed in a natural and free manner and no single concern has yet obtained control of the market.

The domestic consumption has increased from about 350,000,000 pounds in 1900 to 685,000,000 pounds in 1906. In 1907 it had decreased to 485,000,000 pounds. To this should be added the consumption of copper recovered from scrap, which was about 60,000,000 pounds in 1907, making a total consumption of about 545,000,000 pounds.

The uses are principally for wire or other electrical purposes, brass, castings, and sheet copper. There is no such great amount permanently lost as in lead and zinc, and a large quantity of scrap will be available with increased production and consumption.

WASTE.

It is not believed that the waste in the mining of copper ore is excessive. Ores too poor to extract at prevailing prices are, of course, left in the mine. But with present methods of extraction, whether timbering, filling, caving, or steam-shovel methods, there is little profitable ore left in the mines.



THE PRODUCTION OF LEAD IN THE UNITED STATES

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THE PRODUCTION OF LEAD IN THE UNITED STATES

Much larger are the losses in concentration. The principal valuable mineral in the concentrating ores is chalcocite, which is easily slimed; the loss may be 30 per cent of the metal contained, and it is not always easy to avoid it. Storage of tailings should be enforced, even though in many cases the grade of the ore is so low that there is little present probability of utilization. The waste in copper smelting is not large and the slags are easily available for resmelting; at many reduction works old slags are used as a fluxing material.

LEAD.[a]

PRODUCTION OF THE UNITED STATES.

The diagram shows by graphic method the annual production of lead in the United States for the last twenty-eight years. From 129,000 short tons, in 1885, the production increased at a moderate rate to 1895, when it was 170,000 tons, an average increase of about 3,700 tons per annum for eleven years. The second epoch, from 1895 to 1907, presents radically different conditions. The output rose rapidly and steadily, except for small setbacks in 1899 and 1905, at an average increase of almost 15,000 tons per annum, or about four times as rapidly as in the previous eleven years. In 1895 the total was 170,000 tons; in 1907, 365,000 tons. The increase since 1895 has been at an almost even rate, by average, as clearly indicated on the diagram. Should this rate of increase be maintained, the production of 1910 would be 410,000 tons, and that of 1920, 560,000 to 580,000 tons.

PRODUCTION OF THE WORLD.

In 1907 the world's production of lead was about 965,000 metric tons, while that of the United States amounted to 317,500 metric tons, or about one-third of the whole.

The world's production of lead has not advanced at so rapid a rate as that of the United States. From a total of about 721,000 metric tons in 1897 the production has increased to about 965,000 tons in 1907. If we consider all countries except the United States, the figures for the same period of eleven years would be 541,000 tons and 648,000 tons, an average annual increase of 9,700 metric tons. Upon closer examination it is found that the total production of all countries except the United States increased rapidly—in fact, at the remarkable rate of 23,000 tons per annum from 1897 to 1903. On the other hand, a steady decrease has taken place since that time, from 702,000 metric tons in 1903 to 647,000 metric tons in 1907, equivalent to a rate of 11,000 tons per annum. And this has happened in the face of advancing lead prices.

Considering the foreign supply in more detail, the greatest output comes from Spain (186,000 tons in 1907). The quantity has remained approximately constant from 1897 up to the present time. Spain's resources of lead are known to be great, but it may be seriously doubted whether the present production can be materially increased. Germany contributed about 143,000 tons. Up to three or four years ago a steady increase had been shown in Germany, but in the last

[a] Prepared with the assistance of Mr. C. E. Siebenthal, of the U. S. Geological Survey.

few years, in spite of rising quotations, the production has receded. Australia yielded 97,000 metric tons, mainly from Broken Hill, but its output has been decreasing rapidly during the last few years from the maximum of 141,000 metric tons reached in 1903. Practically the same may be said of Mexico. From Mexican ores about 72,000 metric tons of lead were obtained in 1907. The rich ore deposits of Sierra Mojada and other places are being exhausted.

The facts given above are significant. They show that the lead deposits of the world are being heavily drawn upon and that, barring new discoveries of great importance, which are somewhat unlikely, a further reduction in the world's output is likely. This reduction will probably be accompanied by a rise in the price of the metal. An advance of a few cents per pound will no doubt create new and large ore reserves in many countries.

RESOURCES OF THE UNITED STATES.

Of the 365,000 tons of lead produced in the United States in 1907, Idaho and Missouri yielded 236,000 tons, or nearly two-thirds. The output of 1907 was divided approximately as follows:

	Short tons.
Southwestern Missouri	24,600
Southeastern Missouri	98,400
Idaho	113,000
Utah	62,000
Colorado	51,000
Other States	16,000
Total	365,000

In the following pages the production and possibilities of each State are taken up in sequence.

MISSOURI.

In southwestern Missouri lead is now mainly obtained as a by-product from crude zinc ores which average about one-half of 1 per cent in lead. The heavy lead ores occurred near the surface and are now almost exhausted. The present production of lead is mostly derived from the extensive flat ore bodies in the lower Carboniferous, known as the sheet ground. The portion of the sheet ground which has been mined up to date, say, in the last ten or twelve years, while comprising probably the richest part, constitutes not over the one-hundredth part of the probable sheet-ground territory. Much of this territory is, however, not workable at present ore prices. Large and economical plants will be one of the necessities of the future. Decreased cost of production and higher ore prices may lead to the opening of still deeper disseminated deposits which the drill has shown to exist at Joplin, Webb City, and Granby, and which have also been opened 10 miles south of Joplin. It is believed that the deposits of southwestern Missouri will be sufficient to keep up the present production for fifty years at least.

Although the district of Joplin has been examined in detail by the Geological Survey, it is impossible to measure the extent and richness of the probable ore with any degree of certainty. Any estimate in figures is little better than a guess. As lead is here a by-product of zinc-ore mining, what is said of the zinc-ore supplies holds good also for lead ore.

The production of southwestern Missouri remained fairly constant at 27,000 to 35,000 tons of lead concentrates per annum from 1894 to 1905. In 1906 and 1907 a rapid advance took place, and in 1907 about 42,000 tons of concentrates were obtained.

In southeastern Missouri a pure lead ore is mined, containing an average of about 5 per cent of metallic lead. The important ore bodies occur disseminated at the base of a Paleozoic limestone at depths of 300 to 800 feet in fairly well defined runs or ore bodies, some of which are over 5,000 feet in length. The production has been maintained for many years. In 1892 about 42,000 tons of concentrates and shipping ore were obtained. In 1901 this had increased to 110,000 tons. During the last few years the output has increased rapidly, and in 1907, 157,000 tons of concentrates were produced. This rapid advance is chiefly due to the enlarged plants of the St. Joseph Lead Company and affiliated interests, capable of handling 3,900 tons of ore per day, and to the 2,400-ton concentrating mill recently erected by the Federal Lead Company, which is allied to the American Smelting and Refining Company. No data are available giving the results of the extensive prospecting operations by diamond drills undertaken by these companies, nor has the region been covered by the investigations of the United States Geological Survey. Statements obtained from well-informed engineers indicate that the ore-bearing area covers from 30 to 40 square miles. While this ore-bearing area is large, it is by no means inexhaustible. It is believed that the maximum of production will be reached in a few years. The supply will, however, undoubtedly last for a great number of years, and it is undoubtedly true that there is a great extent of unprospected territory with possibilities of ore deposits at a considerable depth, especially on the south and southwest sides of the St. Francis Mountains.

IDAHO.

In Idaho the Cœur d'Alene district is the principal source of production. Discovered about 1885, this district has rapidly and continuously increased its production until it now exceeds 100,000 tons of metallic lead per annum. The deposits are strong fissure veins in quartzite. The principal properties are controlled by the Bunker Hill and Sullivan Mining and Concentrating Company and the Federal Mining and Smelting Company, the latter affiliated with the American Smelting and Refining Company. The district has been studied by Mr. F. L. Ransome, of the Geological Survey,[a] who expresses his belief that the district gives promise of long-continued activity. Mr. Ransome also states that the ore shoots extend to great depth with remarkably little change in the character of the ore. The Bunker Hill and Sullivan mine, which has distributed over $9,000,000 in dividends, may reasonably be expected to continue its present rate of production for a score or more of years. Similar conclusions apply to several other mines. New discoveries will probably be made, as, indeed, in the last few years two important mines have been

[a] Prof. Paper No. 62, U. S. Geological Survey.

added to the producers. The total production of lead and silver will probably continue to increase for several years. The Bunker Hill and Sullivan, the greatest single producer, yielded in 1907 about 35,000 short tons of lead. On its lowest level the ore shoot is said to be as rich as in any of the upper workings, and there seems to be no reason why mining operations could not be extended for several thousand feet below this level. The underground workings have now, according to a recent circular to stockholders, undercut and partially developed 3,000,000 tons of ore, expected to contain 11 per cent of lead and 4.82 ounces of silver per ton, a total of about 330,000 tons of lead. A few of the deeper mines are now, according to Mr. Ransome, extracting ore much leaner than this and may cease to be profitable in a few years. There is also the probability that in general more zinc and less lead will be found as the mines attain greater depth. But on the whole the prospects decidedly encourage the belief that the Cœur d'Alene district will be able to maintain or somewhat increase its present production for some twenty-five years at least.

UTAH.

Utah has long been an important producer of lead, chiefly from three districts, the Park City, Bingham, and Tintic. The Frisco district has lost its one-time prestige in respect to this metal. The total output of Utah now (1907) stands at 64,000 tons, and for a number of years has remained fairly constant. The Park City district is the most productive, yielding about 23,000 tons per annum. The lead ore is contained in strong fissure veins and replacement bodies which promise a long-continued output. The bulk of the remainder, or about 40,000 tons, has until recently been derived from the Bingham and Tintic districts, but in late years the American Fork and Stockton districts have greatly increased their production. Utah is rich in lead ores, and its output bids fair to be continued on the present scale for many years to come. On the other hand, there is little probability of a greatly increased output. Nobody is in position to furnish even approximate figures as to the reserves, and few of the lead mines have, in fact, reserves for more than two or three years ahead.

COLORADO.

Since 1879 Colorado has always been one of the most important lead-producing States. The production reached a maximum when the great ore bodies of Leadville were discovered about twenty-five years ago. It has fluctuated considerably, ranging from 40,000 tons to 80,000 tons of metallic lead between the years 1881 and 1908. During the last few years it has slowly declined and in 1907 was estimated to be 51,000 tons. Leadville has always been the most prominent district and its production was greatest when the enormous bodies of carbonate ore were worked, from 1880 to 1890. During recent years the output of Leadville has remained fairly constant at about 23,000 tons, or one-half of the total production of Colorado. The rich oxidized ores are almost exhausted. The deeper ore bodies are of great size but are poor in lead. It is largely owing to the utilization of zinc ores that Leadville has been able to maintain its production; the tonnage of zinc-lead ores, poor in lead, is now about one-third of the tonnage of the lead ores and the siliceous ores. Undoubtedly a large output of lead can be maintained for many years, but it will probably slowly decrease. The rest of the Colorado lead is mainly derived from Aspen and Creede. The former district is slowly decreasing in importance. Regarding the latter, the information at hand is not extensive, but it is believed that the district is in position to maintain its output for a number of years.

From the preceding it appears that there is little chance of increase in the lead production of Colorado. More probably it will gradually decrease. The State is rather throughly prospected, and the chance of new discoveries is correspondingly small.

OTHER STATES.

None of the other States yield enough to become a seriously considered factor. The total output from them was 16,000 tons in 1907. Probably many districts will increase in importance; others will fall out. For a number of years to come we may count with some confidence on this amount as their aggregate total. The Eureka mines in Nevada, once prominent, are now being reopened, but thus far no ore bodies similar in importance to the old bonanzas have been reported. The railroads now being built in the State will open a considerable territory, which will yield a fairly large amount of lead from newly developed smaller districts or from rehabilitated old districts like Pioche. Discoveries of new lead-producing districts like Leadville or Park City or the Cœur d'Alene are of course always possible, but they do not seem very likely.

Summing up these data, it is believed that the lead production of the United States can be maintained at the present figures for a number of years—possibly twenty years—but that after some such time it would be more likely to decrease. Barring new discoveries of great value, a continued increase of production, like that which has taken place in the United States since 1895, is very improbable. With increasing demands for consumption the price of lead would gradually rise, and in such case of course each cent permanently added to the price of the metal would make available large additional ore reserves, but even at an increased price there is little probability of an indefinite increase on the scale of the last few years.

CONSUMPTION.

For the last ten years the United States has consumed all of the domestic lead produced, and in addition a variable but small amount has been imported. The consumption has practically kept step with the production.

A feature of much interest is that over one-third of the lead is used in the manufacture of white lead and consumed as paint. This feature is shown in the accompanying diagram. In 1907, 135,000 tons of metallic lead were so used. White lead is used more than any other substance for paint, although the manufacture of zinc white and zinc-lead white has taken great steps forward during the last few years. Of course the lead so used is absolutely lost, and it does seem as if for these purposes some other material might be substituted for so valuable a metal, especially when, as shown above, the ore reserves are relatively low. Probably no other nation uses lead paint to the same extent as the United States; partly because here wood construction prevails; partly because our greater prosperity allows the use of more expensive paint. With general substitution of brick, stone, or cement (of which our resources are inexhaustible) for wood (of which our supply is rapidly diminishing), the demand for lead white would greatly decrease. Anything that could be done to encourage this change would be desirable.

SCRAP LEAD.

With increasing production and price a greater quantity of scrap will each year be remelted for consumption. In 1907, according to incomplete returns made to the United States Geological Survey, 25,000 tons of lead were thus returned to consumption; the latter is thus in reality at least 25,000 tons greater than the figures of production would indicate.

WASTE.

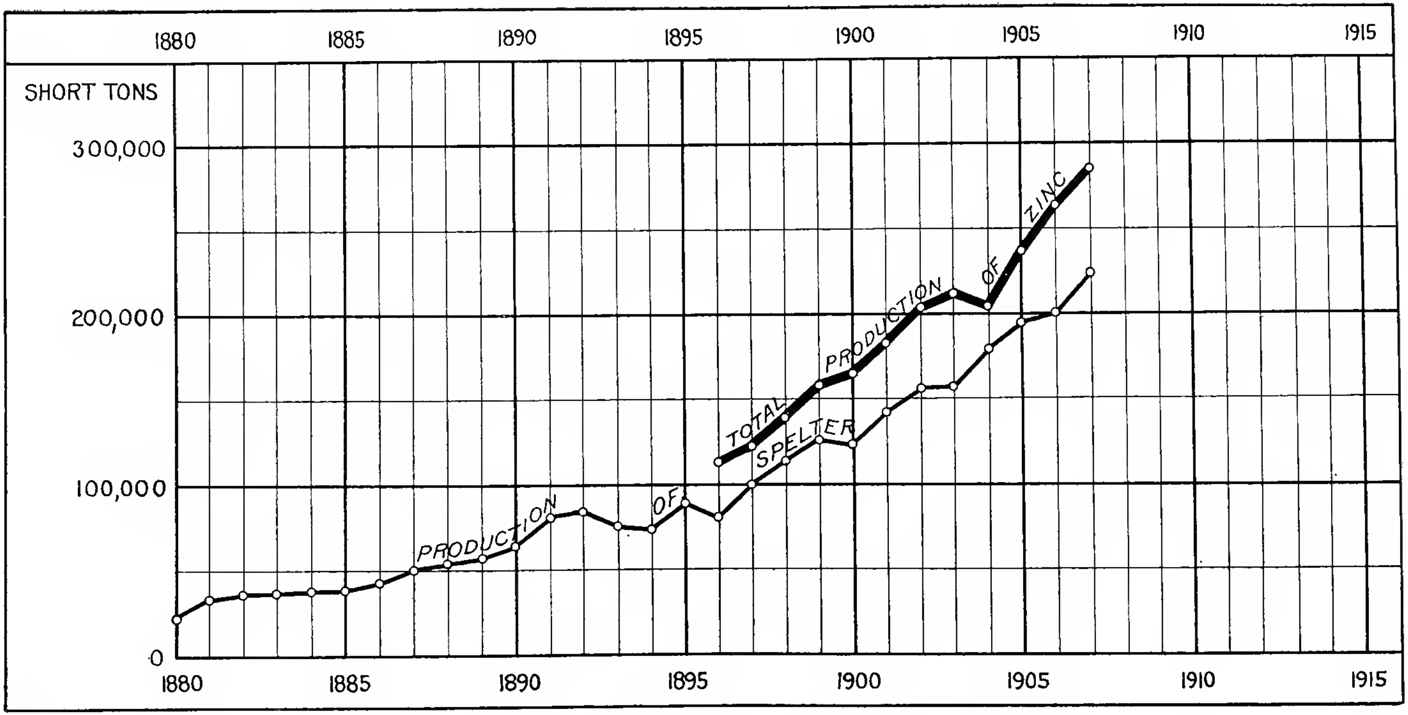
There is little waste in the mining of lead ores. Neither is there much waste in the smelting of the ores; besides, the slags are of course always available for retreatment, if necessary. The loss in smelting and refining is usually estimated as 5 per cent, although this figure is probably somewhat too high.

The greatest waste takes place in the concentration of lead ores. It is not nearly so great as in case of copper and zinc, but doubtless often amounts to 15 per cent. The best way to mitigate this feature would be to compel all owners of concentrating works to store their tailings.

The improvements in both concentration and smelting have been very great in the last fifteen years, and this fact has, of course, enabled the miners to handle lower grades of ore. A lead ore containing 4½ per cent of metallic lead is now worked in southeastern Missouri, and ore containing 5½ to 6½ per cent (with 2 to 3 ounces of silver) in the Coeur d'Alene district. Further reduction in the costs are probable, but not likely to be great as long as the present high scale of wages in the West continues.

TARIFF ON LEAD AND LEAD ORES.

The lead-mining industry has been to a high degree artificially stimulated by the duty on refined lead and lead ores. Under this protection our own resources have been strained to the utmost. We have put a premium on the output of lead and the result is shown in the price of the metal, which is higher in New York than in foreign markets. The control of the market in the United States has not unnaturally fallen into the hands of a trust. Both the smelting and the mining interests have been greatly favored, while the consumer has been paying the bills. Were the duty on lead and lead ore removed the western and central lead-mining districts would no doubt be forced to reduce wages and pay the strictest attenion to reduction of cost. The natural resources would, however, probably be less heavily drawn upon.



THE PRODUCTION OF ZINC IN THE UNITED STATES FROM 1880 TO 1907 (IN SHORT TONS).

Upper line shows total production of zinc as spelter and as zinc in zinc white, manufactured from ore. Lower line shows production of spelter.

ZINC.[a]

PRODUCTION OF THE UNITED STATES.

The zinc-smelting industry in the United States is of comparatively recent origin. From a small beginning of 23,000 tons of spelter in 1880, the production of spelter increased at a moderately rapid rate up to 1896, as shown by the diagram. This total increase in seventeen years was only about 60,000 tons, or at a rate of 3,500 tons per annum. From 1896 a much more rapid rate began. The average increase from 1896 to 1907 was at the rate of 14,000 tons per annum, or from 81,000 tons in 1896 to 223,000 tons in 1907. The rate of increase has been fairly uniform within this period, but was distinctly greater from 1903 to 1907 than from 1896 to 1903, the average annual increase during the former period amounting to 18,000 tons.

All these figures, it should be remembered, refer to spelter; a large part of the zinc ore is, however, used for pigments, chiefly zinc oxide, partly also zinc-lead white. The upper curve in the diagram shows the zinc in pigments added to the production of spelter. The amount of zinc used annually for paints has doubled since 1896 and is now about 60,000 tons. Taking this into consideration it is seen that the total production of zinc in the United States was 284,000 tons in 1907, and that the annual increase since 1904 has been 32,000 tons in 1905, 27,000 tons in 1906, and 21,000 tons in 1907. Assuming that a straight line from 1896 to 1907 represents the average tendency, the production in 1910 would be about 325,000 tons; in 1915, 395,000; and in 1920, 475,000 tons. Should the substitution of zinc oxide for white lead proceed on a still larger scale in the future than in the past, which seems possible, the figures at the years mentioned would be very materially increased.

PRODUCTION OF THE WORLD.

The world's production of zinc has increased since 1896 at a very rapid rate, but not quite at the pace set by the United States. The total production increased from 422,000 metric tons in 1896 to 737,000 metric tons in 1907. The production from all sources, excepting the United States, amounted to 352,000 metric tons in 1896 and 510,000 metric tons in 1907, an average annual increase of 14,300 tons.

The celebrated zinc mines in Belgium are still producing heavily, as are the mines of Silesia and at other points in Germany. New and very extensive supplies of ore are being received in Europe from Mexico and Australia, and deposits of great magnitude are reported to exist in Africa. The successful solution of the problem of ore concentration at Broken Hill, New South Wales, will enormously increase the shipments of Australian ores to European smelters, and it is considered possible that the mines of Germany and Belgium may have to reduce their output to avoid overproduction of zinc.

The United States now ranks first in production, having surpassed Germany in 1907.

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[a] Prepared with the assistance of Mr. C. E. Siebenthal, of the U. S. Geological Survey.

RESOURCES OF THE UNITED STATES.

The production of zinc (spelter and zinc in oxide) in 1907 is divided approximately as follows among the States:

	Short tons.
Missouri	142,000
Wisconsin	20,600
Kansas	14,000
New Jersey	62,500
Colorado	30,400
Other States	14,500
Total	284,000

MISSOURI.

It will be seen that Missouri occupies the most commanding position, producing exactly one-half of the total domestic output. Practically all of this is derived from the southwestern or Joplin district. The ores now of most importance are contained in flat deposits in the so-called "sheet ground," which, at a depth of 150 to 250 feet, underlie a large area in this region. The known sheet ground is constantly increased; the extent of the actual known ore reserves is an unknown quantity; the extent of the area of possible ore is very large. It can be said with fair confidence that deposits of zinc ores underlie 50 square miles of territory, with strong probability that further exploration will add another 50 square miles. The portion of the sheet ground which has been worked during the last ten or twelve years, since such mining was first attempted, is between 1 and 2 square miles. Much of the remaining territory is certainly poor and contains considerably less than 3 per cent of zinc sulphide (including some lead), and whether it can be profitably worked is largely dependent upon royalty to the landowner as well as price of zinc. There is also some probability of opening lower deposits of zinc-bearing ground which have been shown to exist at Joplin, Webb City, and Granby and which now are being worked at Aurora at a depth of 325 feet. Superficial deposits will doubtless continue to be discovered and worked, though probably in lessening number and extent in the future. As the result of special study of the Joplin district by the United States Geological Survey, it is thought that the probable ore reserves will be sufficient to keep up the present production for fifty years at least.

KANSAS AND OKLAHOMA.

The zinc-bearing cherts and limestones extend from Joplin into the adjoining States of Kansas and Oklahoma. In Kansas the future can not be predicted, as the deposits so far developed have not been of sheet formation, but there are possibilities of finding extensive deposits in virgin territory and at greater depth in known localities. In Oklahoma the production is now small, but there are in the Quapaw district at least 12 square miles of ore-bearing blanket breccia. Very promising deposits have been opened at Miami, and the blanket breccia probably extends in this direction, making it reasonably certain that the mineralized area is as much as 20 square miles in extent, most of which will be available mining territory when ore yielding 2 per cent of concentrates can be profitably worked.

WISCONSIN.

According to Mr. H. Foster Bain, the extent of the zinc deposits in Wisconsin is fairly well known. The ore does not, as in Missouri, form extensive flat sheets, but shorter "pitches" and "flats." The zinc ore is usually found below the already mined lead deposits, and drilling operations during the last few years have given encouraging results. The production has increased rapidly and with higher zinc prices will probably increase still further. No estimate of actual or probable ore reserves can be given, but there is little doubt that the present production, with zinc at 5 or 6 cents per pound, can be continued for many years.

NEW JERSEY.

The large and in many respects remarkable deposit at Franklin Furnace is the only occurrence of importance in New Jersey. No recent estimate of the quantity of ore is available, but, according to a report by Nason,[a] the ore body in 1894 contained about 8,000,000 tons. According to the reports of the New Jersey Geological Survey, approximately 2,500,000 tons have been mined since 1904. The figures for the total ore reserves may be rather far off the mark, but they serve to show that the ore body is known to have definite limits and that its exhaustion is probably a matter of fifteen to twenty-five years at the present rate of ore production.

COLORADO.

About 1901 Colorado began to ship zinc ores to the smelters and shortly afterward a zinc smelter was built at Pueblo. The production rose rapidly, and, according to the mine reports of the United States Geological Survey, in 1906 attained 43,000 tons, calculated as probably recovered spelter and zinc in paint. In 1907, when the conditions, at least during the latter part of the year, were less favorable, the production was 30,400 tons. The larger part of this came from Leadville, in which camp the lower levels had disclosed large quantities of ore consisting of pyrite, zinc blende, and a little galena. Recent improvement in concentrating processes had made possible the recovery of this zinc and its separation from the pyrite. Large quantities of zinc also came from the Tenmile, Red Cliff, Aspen, Creede, Breckenridge, and Clear Creek districts. The margin of profit was in many cases small, no payment was as a rule obtained for the silver and lead contained in the ores, and the losses in concentration were great. When the lower prices of 1907 were established the majority of the mines ceased shipments.

No figures of ore reserves even approximately correct are available to the Geological Survey, nor can they be obtained, but there is no question whatever that the resources of Colorado in zinc ores are very large, and that with favorable prices an output much larger than that of 1906 could easily be yielded by the State for a long period of years. The ores occur under entirely differing conditions from those of the Central States. The deposits are fissure veins or irregular replacement ores in limestone, and are nearly always mixed,

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[a] Trans. Am. Inst. Min. Eng., 1894.

i. e., contain silver, copper, lead, and more rarely gold. Many mines once worked for lead have been impoverished by the prevalence of zinc in lower levels.

OTHER STATES.

Conditions similar to those in Colorado prevail in many of the Western States, notably in Utah and Idaho, both of which shipped a considerable amount of zinc ores in 1906 and 1907. From Park City and Frisco in Utah and from the Cœur d'Alene district in Idaho important shipments were made. New Mexico, though not figuring conspicuously in the production of 1907, has some very large zinc deposits at Magdalena and smaller deposits at many places. Its yield of zinc in 1906 was about 8,000 tons, and with favorable conditions this amount could probably be doubled and be continued for a considerable period of years.

Zinc ores in considerable quantities could be furnished by Arizona and Nevada. Prospecting for these ores has not been especially active in the West. In fact, deposits containing zinc have until within a few years rather been shunned on account of the difficulty of treating such ores in copper and lead furnaces and the difficulty of marketing them as zinc ores with profit. New discoveries may therefore be anticipated.

In conclusion, the supply of zinc at prices of 4 to 5 cents is not very large, and will come chiefly from Missouri and New Jersey. At prices above 5 cents the supply will probably be ample for such length of time as we can reasonably foresee. It is thought that our resources of zinc, especially in the West, have just begun to be developed.

CONSUMPTION.

Since 1876 the domestic production has been sufficient to supply the demand, and the importations have been small. A small amount of high-grade spelter and ore has been exported, mostly from New Jersey. There is, it is true, an import duty on spelter practically prohibiting foreign importations, but on the other hand, during the last three years 25,000 tons of spelter have been obtained per annum from Mexican ores, which is equivalent to about one-eighth or one-ninth of our domestic production. There has been a long controversy about the construction of the law in respect to zinc ores. The case is still in the courts and, pending final decision, duties are still collected, to be refunded later should zinc ores be adjudged duty free.

As already noted, about 60,000 tons of the metal are used per annum for the manufacture of white paint. This amounts to one-sixth of the whole output, and is of course permanently lost. Next in importance comes the metal used for galvanizing, and this consumed, in 1905, 100,000 tons; in 1906, 124,000 tons; and in 1907, 149,000 tons, an increase of 49 per cent in two years. In 1907 this amounted to more than half of the total production of zinc. The remainder of the spelter output is about equally distributed between brass and sheet zinc. All these products seem indispensable for the growth and development of the industries, and it is believed that the consumption of zinc will continue to increase at the recent rate for several years to come.

The zinc industry has been less protected than lead mining and smelting. There is no trust controlling the output or the principal part of the output, and it appears to be in a healthy condition. Free importations of zinc ore will act as a healthful check on the too rapid consumption of our resources, and it would probably be well to allow them in the future.

Much zinc can be recovered from the galvanized products, and this recovered metal, which in 1907 amounted to 13,000 tons or more, will of course increase as the output grows larger.

WASTE.

In no metal industry is the waste more startling than it is in the production of zinc. In mining, Missouri must be considered first. Owing to the occurrence of the ore in flat sheets, it is necessary to leave pillars to support the roof, filling or timbering being too expensive. About 14 per cent of the ore therefore remains in the mine, although, of course, care is usually taken to select the poorer ground for pillars as far as possible. In the West, owing to the expensive treatment and shipment of the ore, much low-grade ore is left in the mine, but this is not necessarily a complete loss unless the mine is entirely wrecked.

In concentrating, the losses are enormous. Somewhat better conditions now prevail, but in many cases at least not more than 60 per cent of the assay value is saved in the concentrating works. From 30 to 35 per cent is perhaps an average loss. Southwestern Missouri has been the chief offender in this respect. While the mining and milling costs there have been extremely low, this has been accomplished at a heavy loss of metal. The miner has not been entirely to blame, for the heavy royalties exacted by the landowners have forced him to adopt these wasteful methods. Lower royalties, better concentration works, and obligatory storage of tailings will help these conditions.

In the smelting of zinc ores the loss is heavier than in any other metal; the average is probably nearly 20 per cent of the assay value, and the loss is heavier in western complex ores, containing much iron, than in Missouri Valley ores. It is claimed that the smelter practice has been behind that of Europe. These conditions are being remedied, but still further metallurgical improvements are most urgently desirable and will be soon attained. The western ores usually contain silver and lead; sometimes also copper. Under present conditions these metals are often wasted, and only under exceptional conditions does the miner obtain payment for them. There is vast room for improvements in the zinc industry, and attention to the matter will materially increase the life of our zinc deposits.

The total loss from ore in the ground to spelter is rarely less than 40 per cent.

THE PHOSPHATE DEPOSITS OF THE UNITED STATES.

By F. B. Van Horn,
United States Geological Survey.

INTRODUCTION.

The occurrence of rock phosphates in the United States has a very important bearing upon the agricultural industry, since many plants can not exist without the presence of phosphoric acid in the soil. Growing crops deplete the soil of its phosphoric acid, and if no steps are taken to restore this substance the soil must eventually become non-producing.

Florida, South Carolina, and Tennessee have for several years been the main sources of phosphate in the United States. North Carolina, Alabama, and Pennsylvania have produced phosphate rock, but never on a large scale, and there is at present no production from these States. In 1900 Arkansas entered the field as a producer, and in 1906 a new field was discovered in Wyoming, Idaho, and Utah.

DEVELOPMENT OF THE INDUSTRY.

Phosphate mining began in the United States in 1867 in South Carolina. The existence of the rock had been known since 1837, but the possibilities of its commercial use were not recognized until 1859. According to Otto A. Moses:[a]

In 1859 Professor Shepard and Col. L. M. Hatch suggested the utilization of phosphatic marls in the manufacture of commercial fertilizers and started a factory at or near Charleston, which was, however, soon abandoned. Remains of their compost heap were utilized by neighboring farmers with good effect long after the war.

At the close of the war Dr. N. A. Pratt, formerly connected with the niter bureau of the Confederacy, visited Charleston with the object of starting sulphuric acid chambers. About this time Dr. St. Julien Ravenel, of Charleston, who had mined marl extensively at Stoneys Landing, on Cooper River, for the manufacture of cements, noticed the nodules, analyzed some of them, and found them to contain much phosphate of lime. He became engaged soon after in the manufacture of commercial fertilizers from foreign phosphate rocks. Then followed the discovery (in August, 1867) which has been of such vital importance to agriculture and the prosperity of South Carolina. Pratt and Holmes (Charleston Mining Company), Ravenel and Dukes (Wando Company), then located territory. The value of the deposits became known; other available beds were discovered, and many persons and considerable capital were soon employed in developing the new industry by mining the crude rock and exporting or manufacturing it on the spot into superphosphates. Later on the beds of many navigable streams were found to be largely paved with the valuable substance.

[a] Mineral Resources U. S. for 1882, U. S. Geol. Survey, 1883, p. 512.

Until 1888 South Carolina enjoyed a monopoly of the phosphate industry of the United States. In that year Florida came forward as a phosphate State, with a production of 3,000 long tons. In 1904 the production surpassed that of South Carolina, and Florida has maintained its lead up to the present time.

In 1892 phosphate was discovered in Tennessee, and two years later the production from that State was 19,188 long tons. In 1899 Tennessee went ahead of South Carolina, the production from the latter State having decreased steadily since 1894.

PRODUCTION.

The production of phosphate from South Carolina from the beginning of the industry in 1867 to the year 1888, during which period that State was the only producer, was 4,442,945 long tons, valued at $23,697,019. The following table shows the total production from the United States from 1867 to 1907:

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Long tons.			*Long tons.*	
1867–1887	4,442,945	$23,697,019	1899	1,515,702	$5,084,076
1888	448,567	2,018,552	1900	1,491,216	5,084,248
1889	550,245	2,937,776	1901	1,483,723	5,316,403
1890	510,499	3,213,795	1902	1,490,314	4,693,444
1891	587,988	3,651,150	1903	1,581,576	5,319,294
1892	681,571	3,296,227	1904	1,874,428	6,580,875
1893	941,368	4,136,070	1905	1,947,190	6,763,403
1894	996,949	3,479,547	1906	2,080,957	8,579,437
1895	1,038,551	3,606,094	1907	2,265,343	10,653,558
1896	930,779	2,803,372			
1897	1,039,345	2,673,202	Total	29,208,141	117,316,002
1898	1,308,885	3,453,460			

Of this amount South Carolina has furnished 11,912,959 tons; Florida, 12,395,731 tons; Tennessee, 4,859,991 tons; and other States, 40,460 tons. In twenty years Florida has produced more phosphate than has South Carolina in thirty-one years.

GEOLOGIC OCCURRENCE.

The phosphate deposits range in age from the Ordovician in Tennessee to the Tertiary in Florida, occurring also in the Devonian in Tennessee and Arkansas, and in the Carboniferous in the Wyoming-Idaho-Utah field.

FLORIDA DEPOSITS.

DISTRIBUTION.

Phosphates occur in a general way along the west coast of Florida, principally in Polk, De Soto, Hillsboro, Pasco, Hernando, Sumter, Citrus, Marion, and Levy counties, although the rock has been found also in Alachua, Suwanee, Lafayette, Taylor, Jefferson, Wakulla, and Liberty counties. There are three classes of deposits in Florida—hard rock, land pebble, and river pebble. These deposits vary in percentage of tricalcium phosphate from 78 per cent to 80 per cent in the hard rock, through 68 per cent to 70 per cent in the land pebble, to about 65 per cent in the river pebble.

Hard rock.—The hard-rock phosphate belongs to the Eocene and the Miocene periods. In the former it consists entirely of a bowlder deposit in a soft matrix of phosphatic sands, clays, and other materials, while in the latter it is also found at many places as a bedded deposit in situ. The bowlders vary in size from 2 or 3 inches to 8 or 10 feet, and lie embedded in all positions, surrounded by sand and clay containing more or less phosphate of lime in finer particles, resulting from a general distribution of the disintegrated portions of the bowlders during deposition. The deposits themselves vary from small pockets to those several acres in extent. The phosphate content of this class of deposits is from 10 per cent to 30 per cent of the mass.

Land pebble.—The pebbles making up this deposit range from minute size to that of a walnut. They are originally white in color, but become dark colored when subjected to water action. They are embedded in sand and are underlain by a stratum of tough, stiff, clayey material known as "bed rock." Above the deposit is an overburden from 1 to 25 feet thick consisting of sand and limestone bowlders. The proportion of phosphate to other rock of this class of deposits varies from 1 to 10 to 1 to 4, or from 10 per cent to 25 per cent.

River pebble.—This class of deposit is very similar to the land pebble and derives its name from its manner of occurrence in the river beds. The pebbles are white to dark brown in color and of about the same size as the land pebbles. They occur in the form of bars in the rivers, and are derived from the formations through which the river flows.

DEVELOPMENT AND PRODUCTION.

The year 1887 marked the beginning of the phosphate industry in Florida. In 1888 the first shipment of pebble phosphate from Peace River was made to Atlanta, Ga. In 1889 the hard-rock phosphate was discovered in Marion County, and in 1890 the land-pebble area was opened up in Polk County. The growth of the industry has been rapid and remarkable, until now Florida is the largest producer of phosphate rock in the United States.

The first production consisted of 3,000 tons in 1888, and twenty years later the output for the year was 1,357,365 tons, or nearly 60 per cent of the entire production of the United States in 1907. Following is a table showing the marketed production and value of phosphate rock from Florida, by years, since the first shipment:

Output of phosphate rock in Florida, based on marketed product, 1888–1907.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Long tons.			*Long tons.*	
1888	3,000	$21,000	1899	726,420	$2,804,061
1889	4,100	28,000	1900	706,243	2,983,312
1890	46,501	338,190	1901	751,996	3,159,473
1891	112,482	703,013	1902	785,430	2,564,197
1892	287,343	1,418,418	1903	860,336	2,986,824
1893	438,804	1,979,056	1904	1,072,951	3,974,304
1894	527,653	1,666,813	1905	1,194,106	4,251,845
1895	568,061	2,112,902	1906	1,304,505	5,585,578
1896	495,199	1,547,353	1907	1,357,365	6,577,757
1897	552,342	1,493,515			
1898	600,894	1,847,796	Total	12,395,731	48,043,407

SOUTH CAROLINA DEPOSITS.

DISTRIBUTION.

The South Carolina phosphate beds occur interruptedly along a belt the lower limit of which extends along a meandering line from a point near the source of the Wanda River in Charleston County to the mouth of the Broad River. The belt follows the coast, running back as far as 20 miles from the ocean.

In South Carolina the phosphate rock occurs in two forms: The land rock and the river rock, running about 58 and 55 per cent in tricalcium phosphate.

Land rock.—The land rock is very probably of Miocene age, and consists of so-called pebble rock which is in fact a solid mass from which the calcium carbonate has been leached out and partially replaced by phosphate, leaving cavities which connect and penetrate through the rock, giving it the appearance of being made up of separate pebbles. The rock runs from 1 to 3 feet in thickness, and is overlain by a greensand marl.

River rock.—The river rock is so called because it is mined from the river channels. It consists essentially of the water-rounded fragments of the land rock.

DEVELOPMENT AND PRODUCTION.

As already stated, phosphate rock was discovered in South Carolina in 1867, during which year 6 tons were marketed. From this time on the production increased until 1889, when it amounted to 541,645 long tons. Since 1893 the production has almost steadily decreased, and in 1899 Florida took the lead in the industry. In 1907 only 257,221 tons were marketed from South Carolina. The total production and value of phosphate rock from South Carolina, by years, from 1867 to 1907, is shown in the following table:

Production of marketed phosphate rock in South Carolina, 1867–1907.

Year ending—	Quantity.	Value.	Year ending—	Quantity.	Value.
May 31—	*Long tons.*		December 31—Continued.	*Long tons.*	
1867	6	....	1888	448,567	$2,018,552
1868	12,262	....	1889	541,645	2,892,276
1869	31,958	....	1890	463,998	2,875,605
1870	65,241	....	1891	475,506	2,948,138
1871	74,188	....	1892	394,228	1,877,709
1872	58,760	....	1893	502,564	2,157,014
1873	79,203	....	1894	450,108	1,745,576
1874	109,340	$7,248,380	1895	431,975	1,411,032
1875	122,790	....	1896	402,423	1,181,649
1876	132,478	....	1897	358,280	986,572
1877	163,000	....	1898	399,884	1,107,272
1878	210,322	....	1899	356,650	1,078,099
1879	199,365	....	1900	329,173	1,041,970
1880	190,763	....	1901	321,181	961,840
1881	266,734	1,980,259	1902	313,365	919,725
1882	332,077	1,992,462	1903	258,540	763,803
1883	378,380	2,270,280	1904	270,806	861,317
1884	431,779	2,374,784	1905	270,225	878,169
1885	395,403	2,339,468	1906	223,675	817,068
December 31—			1907	257,221	980,867
1885	277,789	1,805,629			
1886	430,549	1,848,939	Total	11,912,959	53,221,272
1887	480,558	1,836,818			

TENNESSEE DEPOSITS.

DISTRIBUTION.

The deposits of phosphate in Tennessee lie mainly in Maury, Hickman, Perry, and Lewis counties, with some deposits in Giles, Williamson, Davidson, Sumner, and Decatur counties.

There are three commercially important classes of phosphate rock in Tennessee: The brown residual phosphate, the blue or black bedded phosphate, and the white phosphate. These range in phosphatic content from 70 per cent to 80 per cent lime phosphate in the brown rock to 75 to 85 per cent lime phosphate in the white rock, although in all three classes are to be found portions which run as high as 90 per cent.

BROWN RESIDUAL PHOSPHATE.

This variety of phosphate occurs mainly in Maury County. It is of Ordovician age, and is the result of the leaching process to which the phosphatic limestones have been subjected. Surface waters bearing carbonic and other organic acids have dissolved and carried away a large part of the calcium carbonate forming the limestone, leaving the calcium phosphate as a residual deposit. The brown phosphate is from 2 to 6 or 8 feet in thickness at various points.

BLUE OR BLACK BEDDED PHOSPHATE.

These deposits are of Devonian age, and show variations from oolitic through compact and conglomeratic to shaly forms. There is also a nodular variety which occurs in a greensand formation immediately overlying the black shale. The bedded deposit occurs in seams varying from 1 to 50 inches in thickness, but where carrying high-grade rock the bed is seldom more than 20 inches thick. The phosphatic content ranges from 30 to 85 per cent. The nodular variety, which is embedded in a greensand matrix, runs about 60 per cent lime phosphate, but it is not practicable to work it except at points where the bedded rock is mined by stripping off the over burden.

WHITE PHOSPHATE.

This rock is of post-Tertiary age, and occurs in three different forms, stony, brecciated, and lamellar. The stony phase contains usually only about 50 per cent of lime phosphate and is not worked at the present time. The lamellar forms were deposited in caves, and are thus of irregular shape and extent. The breccia consists of fragments of Carboniferous chert cemented by lime phosphate. The chert fragments vary from a fraction of an inch to 3 or 4 inches in diameter. The lamellar variety consists of thin parallel layers or plates about 1 inch thick, but several inches long and broad.

The white phosphate has thus far been found only in Perry and Decatur counties. It runs sometimes as high as 85 per cent phosphate of lime.

DEVELOPMENT AND PRODUCTION.

The blue bedded phosphate of Tennessee was discovered in 1893 and was mined until 1896, when the brown rock was found to be valuable. The favorable location of this brown rock led to the cessation of blue-rock mining for the time. The white rock has not as yet been extensively mined.

The total production of phosphate rock from Tennessee from the first operations in 1894 to the end of 1907 is as follows:

Production of marketed phosphate rock in Tennessee, 1894–1907.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Long tons.			*Long tons.*	
1894	19,188	$67,158	1902	390,799	$1,206,647
1895	38,515	82,160	1903	460,530	1,543,567
1896	26,157	57,370	1904	530,571	1,745,054
1897	128,723	193,115	1905	482,859	1,633,389
1898	308,107	498,392	1906	547,677	2,147,991
1899	424,109	1,177,160	1907	638,612	3,047,836
1900	454,491	1,328,707			
1901	409,653	1,192,090	Total	4,859,991	15,920,636

ARKANSAS DEPOSITS.

The developed phosphate deposits of Arkansas are on Lafferty Creek, on the western edge of Independence County. The rock itself is light gray, homogeneous, and conglomeratic, with small pebbles more or less angular in form. The phosphate bed runs from 2 to 6 feet in thickness, and varies from 25 to 73 per cent phosphate of lime.

DEVELOPMENT AND PRODUCTION.

The Arkansas phosphates as such were discovered in 1895, but it was not until 1900 that any attempt was made to develop them. At that time the Arkansas Phosphate Company was formed, and a mining and milling plant was erected. After only a few months' operation this plant was destroyed by fire, and it has only been within the last two years that any production has been marketed, and that has been a small one. Analyses show that very little of this rock is high grade, and the field will probably not be operated until 30 to 50 per cent rock can be utilized.

WYOMING-IDAHO-UTAH DEPOSITS.

DISTRIBUTION.

Within the last few years a large area of phosphate-bearing rock has been discovered in the western United States. This discovery is of much importance since it opens a new field in an area which is tributary to the great agricultural region of the Middle West. The phosphate occurs over a considerable area in southeastern Idaho, southwestern Wyoming, and northeastern Utah. It is found in rocks of upper Carboniferous age in a series of shales and limestones, 100 feet thick, within which are several beds of phosphate rock ranging in thickness from a few inches to 10 feet. At the base of the series is a limestone, and 6 to 8 inches of soft brown shale separates this from the principal phosphate bed, which is 5 to 6 feet thick. This phosphate bed is oolitic in character and high in phosphoric acid. There are several other beds ranging from a few inches to 10 feet in thickness, separated by thin beds of limestone or shale, in the series. Usually one and sometimes two of these beds at a given section are workable, and probably some of the others will eventually be mined. The lime phosphate content in the workable beds varies from 65 to 80 per cent, with an average of 72 per cent.

DEVELOPMENT AND PRODUCTION.

The newness of the field, the lack of transportation facilities, and the high freight rates have prevented the development of this phosphate territory to a great extent, although there has been some shipment from Montpelier, Idaho, in the last two years. According to F. B. Weeks,[a] who recently prepared a report upon these phosphates:

This field embraces the largest area of known phosphate beds in the world, and at some future time it will doubtless furnish a large part of the world's production of commercial fertilizer. The development of intensive farming as a result of the reclamation of arid lands in the West will afford an increasing home market.

PHOSPHATE AS A FERTILIZER.

According to a letter from Dr. W. L. Rasin, of Baltimore:[b]

The manufacture of chemical fertilizers in the United States began about 1850. In that year Dr. P. S. Chappell and Mr. William Davison, of Baltimore, made some fertilizer in an experimental way. About the same time Professor Mapes was experimenting. Later De Burg utilized the spent bone black derived from the sugar refineries and made quite a quantity of "dissolved bone black" (superphosphate). In 1853 or 1854 Dr. P. S. Chappell commenced the manufacture of fertilizers, as did B. M. Rhodes, both of Baltimore. In 1855 Mr. John Kettlewell, recognizing the fact that Peruvian guano (then becoming quite popular and containing at that time 18 to 21 per cent ammonia) was too stimulating and deficient in plant food (phosphates), conceived the idea of manipulating the Mexican guano, containing no ammonia but 50 to 60 per cent of (bone) phosphate of lime, and called his preparation "Kettlewell's manipulated guano."

While in 1856 the sales of Peruvian guano had increased to 50,000 tons, and of Mexican guano to some 10,000 tons, there was not at that date 20,000 tons of artificial fertilizers manufactured in the entire country. Baltimore was not only the pioneer but the principal market for fertilizers until some time after the civil war.

In 1859 a fertilizer plant was built at Charleston, S. C., by Professor Shepard and Col. L. M. Hatch, but it was soon abandoned. Since the discovery of valuable deposits of phosphate rock in South Carolina in 1867, the fertilizer industry has grown rapidly, and in 1900 there were 478 factories in the United States, with an output of 2,887,004 tons of fertilizer, valued at $41,997,673.

AVAILABLE PHOSPHATE DEPOSITS.

The known phosphate deposits of the United States are distributed principally among four localities: (1) Along the west coast of Florida, going back 20 to 25 miles inland; (2) along the coast of South Carolina, extending 6 to 20 miles inland; (3) in central Ten-

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[a] Contributions to economic geology, 1907, pt. 1: Bull. U. S. Geol. Survey No. 340, 1908, pp. 441-447.

[b] Twelfth Census Report, Vol. X, Pt. IV, p. 562.

nessee; and (4) in an area comprising southeastern Idaho, southwestern Wyoming, and northeastern Utah. In addition to these areas some deposits occur in north-central Arkansas, along the Georgia-Florida state line, in North Carolina, Alabama, and Mississippi, but these are mainly of low grade and not utilized at the present time. The first three of the important deposits have been worked for ten to thirty years, while the fourth is a new field which has as yet had but a small output.

Owing to very incomplete data any estimate as to available supply of phosphate rock must, at best, be unsatisfactory. Taking South Carolina as the field most likely to first reach the exhaustion point, Florida second, Tennessee third, and the practically untouched deposits of Idaho-Wyoming-Utah last, an estimate of the available supply and possible duration is given, based on the past production.

South Carolina.—By reference to the table of total production (p. —) it will be seen that the output gradually increased from 1867 until 1889, when the largest production, 541,645 long tons, was marketed. Since 1893 the output has decreased at about the same rate as the increase previous to that year. In the twenty-seven years from 1867 to 1893 the production was 7,269,453 long tons, and in the fourteen years since 1893 the production has been only 4,643,506 tons, or 63.8 per cent of the production to 1893. Arguing from these figures, it is safe to say that the amount of phosphate rock remaining to be mined in South Carolina is not more than 3,000,000 tons, but it is possible that by careful deeper prospecting these figures may be increased. At the present rate of production this field has a probable life of not more than fifteen years.

Florida.—The total production of phosphate rock in Florida since the beginning of the industry in 1888 has been 12,395,731 tons. As shown by the table on page 560 there has been a steady increase in production, but since 1904, when the increase in output over the previous year was 212,615 tons, the increase has been smaller each year, until in 1907 it was only 52,860 tons. When it is remembered that the phosphate deposits in Florida are not continuous beds, but rather pockets, and that practically all the phosphate-bearing areas in the State have already been discovered, it appears conservative to estimate an available supply remaining at not more than 15,000,000 tons, or a little more than has already been produced. At the present rate of production the phosphates of Florida would have a life of approximately twelve years.

Tennessee.—The total production of phosphate rock in Tennessee since the discovery in 1893 has been 4,859,991 tons. In 1907 the production was the largest in the State's history, amounting to 638,612 tons. In Tennessee the phosphates exist as brown rock, blue bedded rock, and white rock. The brown rock is the result of leaching processes in an original phosphatic limestone and occurs usually on the surface. The ease of mining and accessibility to transportation have contributed to the rapid working out of this class of rock, but there still remains enough of it to last possibly five years at the present rate of production; that is, about 3,000,000 tons. The blue bedded rock has not been worked considerably in the past, but with the approaching exhaustion of the brown rock a good deal of activity is now being shown. The bedded character of this rock and its continuity over large areas make it certain that large amounts are still available. According to the American Fertilizer for November, a company has been organized and has taken up 16,375 acres of phosphate land, with 10,000 acres under option. An estimate of 1,500 tons to the acre gives approximately 40,000,000 tons, but this estimate is very conservative. The phosphate rock is heavy, weighing about 175 pounds to the cubic foot. Supposing workable phosphate rock 1 foot in thickness to underlie the 26,375 acres, there would be approximately 100,500,000 tons as an available supply in this territory, more than two and one-half times the amount estimated by the American Fertilizer. With the 3,000,000 tons of brown rock estimated, there would be a total available supply of 103,500,000 tons remaining in Tennessee. At the present rate of production in Tennessee this would last about 160 years. But with the exhaustion of the South Carolina and Florida deposits in twelve years the burden of the industry would fall on Tennessee and the western deposits. In case Tennessee furnished all the phosphates for the country, at the present rate of total production, after the South Carolina and Florida deposits are exhausted in twelve years, the Tennessee deposits would give out about 1960. These figures do not include vast quantities of rock running from 25 to 50 per cent lime phosphate, which are not at present workable.

Wyoming-Idaho-Utah.—The production from this field has not been sufficient to warrant mention, nor has enough detailed work been done in the area to afford a good basis for figuring available supply.

F. B. Weeks, of the Geological Survey, has made a reconnaissance report on the district, from which a very rough estimate of the available rock may be made. The phosphate formation consists of phosphatic limestones and shales 80 to 100 feet in thickness, varying in lime phosphate from 65 to 80 per cent in the workable beds to 20 to 50 per cent in the portion not at present workable. This series dips at all angles from 20° to 90°, thus giving a much larger possible tonnage than would be expected from the superficial extent of the deposits. The formation is cut by faults to a very great extent.

The area underlain by phosphate in the western field is almost wholly public land. Only one claim, the Waterloo placer claim, has been patented, but much land valuable for its phosphate deposits has been staked out in claims, of which there are not to exceed 200 in the aggregate. The engineer of the Waterloo property claims 1,000,000 tons of rock in sight above the valley, without taking into consideration the rock underground where the steep dip carries it from the mountain side. There are perhaps 200 other claims on which development work is being done at the present time. If each of these claims is but half as rich as is the Waterloo, they would represent an available supply of 100,000,000 tons in this field, a supply sufficient to furnish the entire production of the United States, based on the 1907 output, for forty-four years. It is to be understood that these figures do not include the immense quantities of low-grade rock which underlie the western field, nor do they take into consideration the quantities which are at present too deep to be profitably worked. With no more reliable figures at hand, this estimate is offered for the high-grade phosphate rock at present actually available in the Wyoming-Idaho-Utah field. Doubtless before the high-grade rock is exhausted some method will be devised for making use of the low-grade rock, which is at present unavailable both in Tennessee and the West.

Arkansas.—Phosphate deposits are known to occur in Arkansas, but they have not been mined to any large extent. They are apparently of low grade, and large quantities are not to be counted on until rock containing 30 to 50 per cent lime phosphate can be utilized for fertilizer manufacture. This material would not, therefore, be classed as available at this time.

EXPORTATION.

In 1907 there were 2,265,000 tons of phosphate rock produced in the United States. Of this amount over 900,000 tons, or about 40 per cent, was exported. It is not difficult to see that, with our steadily increasing population, the time is not very far distant when the farm lands of the Middle West will be burdened to their fullest capacity. It has been shown, as the result of agricultural experiment station work in Wisconsin, Ohio, and Illinois, that in fifty-four years soils of these States in the cropped areas have been depleted of one-third of their original phosphoric acid. This is equivalent to 20 pounds per acre annually. Assuming it to be only half this amount for the 400,000,000 acres of cropped land in the United States, it would require 6,000,000 tons of phosphate rock annually, or nearly three times our 1907 production, to offset this loss, without considering the question of increasing the productivity. With the reclamation of the arid lands of Wyoming and other Western States will come a period of intensive farming, and in order to produce the large crops which will be required of them, these lands must soon have the assistance of artificial fertilizer. We will have enough to do to take care of our own farm lands without shipping our phosphate rock to foreign countries, and in justice to future generations exportation should be stopped.

Total tonnage available.—Following is a table showing the estimated tonnage of phosphate rock available at the present time in the United States.

	Tons.
South Carolina	3,000,000
Florida	15,000,000
Tennessee	103,500,000
Western States	100,000,000
Total	221,500,000

ESTIMATED LIFE OF PHOSPHATE DEPOSITS.

The rate of increase in production for the past twenty years has been 117 per cent for each decade. Assuming that this rate of increase will continue, it will require just twenty-five years to exhaust the available supply of phosphate rock in the United States. The annual production, at the above rate of increase, will be approximately 17,000,000 tons in 1932.

It is hardly probable that the rate of increase in production will be so great as for the past decade, since the agricultural lands of the Middle West do not at present need artificial assistance. But increasing population with its accompanying intensive farming will eventually force these States to the use of fertilizing materials. The reclamation of arid lands in the West will probably postpone the day, but even those lands will early need some assistance to grow the large crops which will be required of them.

Of course the vast amount of low-grade rock which is not now available will be in reserve, and sometime before the exhaustion of the high-grade phosphates we will doubtless have begun to use this rock. The increasing price of the 60 to 80 per cent phosphate will have a hastening effect on the utilization of the present low-grade material. We have the deposits of Arkansas, Georgia, North Carolina, Alabama, Tennessee, and the West, which run from 30 to 50 per cent in lime phosphate, to draw upon after the high-grade rock is exhausted. This class of deposits, especially in Tennessee and the Western States, will afford an enormous tonnage.

There is still the chance of the discovery of more phosphate fields, and probably the Wyoming-Idaho-Utah field will produce far more than estimated, but based upon present available deposits the life of the phosphates must at best be a short one.

FOREIGN DEPOSITS.

Deposits of phosphate rock exist in Algeria, France, New Zealand, Canada, Russia, Spain, Tunis, Belgium, French Guiana, and some of the South Sea Islands. The deposits of France and Belgium are practically exhausted, only those of low grade remaining. Concerning the other countries, no information as to reserve tonnage is at hand except for the three South Sea Islands—Ocean, Pleasant, and Makatea. These islands have deposits which are estimated to contain an aggregate of 60,000,000 tons of high-grade phosphate rock.

UTILIZATION OF THE PHOSPHATES.

From the above figures it will at once be seen that the utilization of our phosphate deposits to the best possible advantage is imperative. Our farm lands must be preserved for future generations. The phosphate rock of South Carolina is practically exhausted; the Florida deposits have reached their maximum production; the output of the Tennessee deposits is on the increase, but this field alone would, at the present rate of increase in production, last only eleven years. There is some phosphate in Arkansas, but it is of low grade; therefore the large deposits of the public-land States must be depended on for the greater part of our phosphate in the future. The conservation of our phosphate deposits can be best accomplished in the following ways:

1. *Correction of wasteful mining methods.*—The waste involved in mining phosphates, especially in Tennessee, should have some attention. In order to get the largest quantity of high-grade rock necessary for the export trade, large amounts of 50 per cent rock are thrown on the dump and wasted. The time is sure to come when 50 per cent rock, and even 25 per cent rock, will be utilized in fertilizer manufacture. Steps should be taken now to prevent this waste in order to avoid a similar mistake when the phosphates of the Western States are mined. Much of the western rock runs from 25 to 50 per cent lime phosphate, and such material should be saved toward the

time when the term "high-grade rock" will come to mean a lime phosphate content of 40 to 50 per cent instead of 70 to 80 per cent as at present.

2. *Utilization of sewage.*—One of the important sources of phosphoric acid to which we must look in the future is the human excrement which is now being wasted through the present systems of sewage disposal. Van Hise says:

Whitson estimates that the loss in the cities due to man alone is the equivalent of 2 or 3 pounds of phosphoric acid per acre for the entire cropped region of the United States. Supposing this loss to be 2 pounds, this is one one-thousandth of a ton, which amounts for the 400,000,000 acres to 400,000 tons of phosphoric acid, or equivalent to 1,200,000 tons of phosphate rock.

The significance of these figures will at once be seen when it is known that the total production of phosphate rock in the United States for the year 1907 was 2,265,343 tons.

3. *Leasing of the phosphate deposits.*—Only by preventing or materially curtailing exportation can we be assured of the use of our phosphate deposits for our own lands in the future. The following table shows the production and exportation of phosphate since 1900:

Table showing production and exportation of phosphate rock in the United States, 1900–1907.

Year.	Production.	Exportation.	Year.	Production.	Exportation.
	Long tons.	*Long tons.*		*Long tons.*	*Long tons.*
1900	1,491,216	776,220	1905	1,947,190	879,979
1901	1,483,723	624,996	1906	2,080,957	964,241
1902	1,490,314	747,672	1907	2,265,343	900,983
1903	1,581,576	817,503			
1904	1,874,428	849,130	Total	14,214,747	6,560,724

From this table it will be seen that over 46 per cent of the phosphate rock produced in the United States since 1900 has gone to foreign countries. In this connection the American Fertilizer for November gives an account of the organization of the Franco-American Consolidated Phosphate Company, with a capitalization of $7,500,000. The capital stock is fully paid up, and is divided as follows: $5,250,000 for the purchase of phosphate lands in Tennessee, and $2,250,000 for the purchase of fertilizer plants in Europe and for working capital. The company is headed by a powerful syndicate of leading fertilizer manufacturers and bankers of France, Spain, Italy, and Belgium, who will control the stock of the company; and by this organization the fertilizer industry of Europe is expected to be completely under its control.

The company has purchased 16,375 acres of phosphate lands, and has 10,000 acres more under option. Among their plans it is stated:

The company has contracted all of the export rock it can produce for the next ten years, and has concluded arrangements for the immediate introduction, on a large scale, of the blue rock, both in Europe and in this country.

From this it would appear certain that the phosphate deposits of the United States are to be drained for the benefit of the worn-out farm lands of foreign countries. So far as the deposits of Florida, Tennessee, and South Carolina are concerned, this can not be easily prevented, but the production of the newly opened western fields may be preserved for the United States by retaining in the Government title to all the phosphate rock in the lands now belonging to the United States, and leasing these deposits under appropriate terms. In the lease could be included a clause providing that the lessee shall agree to mine phosphate rock only for home consumption.

If all the lands containing phosphate were reserved pending leasing, it would remove from entry certain lands which might otherwise be occupied by home seekers, and it is therefore necessary to provide for the disposal of surface rights alone. Such a separation of surface and mineral rights would obviate the necessity of creating large phosphate reserves in which the surface lands would be removed from settlement; it would permit the fullest utilization of the land in all particulars. A separation of surface and mineral rights would furthermore insure the proper utilization of all phosphate deposits which may hereafter be found in lands now belonging to the United States.

TENURE OF MINERAL LANDS.

By C. W. Hayes,
United States Geological Survey.

There is unquestionably a strong tendency toward the segregation of mineral properties; it is stronger, however, in connection with some minerals than with others. The tendency is probably greatest in connection with iron ores. The reasons are that the iron-making industry itself has in recent years been consolidated under the control of a comparatively few companies, and these companies have in most cases pursued the policy of securing their own ore reserves. Thus the Steel Corporation probably controls 75 per cent of the iron ore in the Lake Superior and southern Appalachian districts.

The tendency to segregate is less strongly marked in the case of coal. This appears to be due chiefly to the fact that coal mines may be developed on comparatively small capital, and to the further fact that the market for the product is very widely disseminated, whereas iron ore, even when produced independently of the companies owning the furnaces, is disposed of to a relatively few purchasers.

Intermediate between iron ore and coal are deposits of the precious and semiprecious metalliferous ores. The extent to which these are segregated in a few hands is determined largely by the geographic position, although the character of the ore and the necessity for obtaining suitable furnace mixtures is also a factor.

The tendency to segregate in case of the minor minerals is not strong. Thus the production of barite, mica, corundum, graphite, feldspar, pyrite, manganese, etc., comes from a large number of small independent producers. The production of sulphur in this country is a monopoly, not by reason of the segregation of separate properties, but through the possession of a patented method for extracting the sulphur from the deposit. An attempt was made to secure control of the production of salt, but the movement failed. The production of petroleum has remained in a large number of separate companies chiefly because such a condition was most satisfactory to the principal refining companies.

MINERAL RESOURCES OF ALASKA.

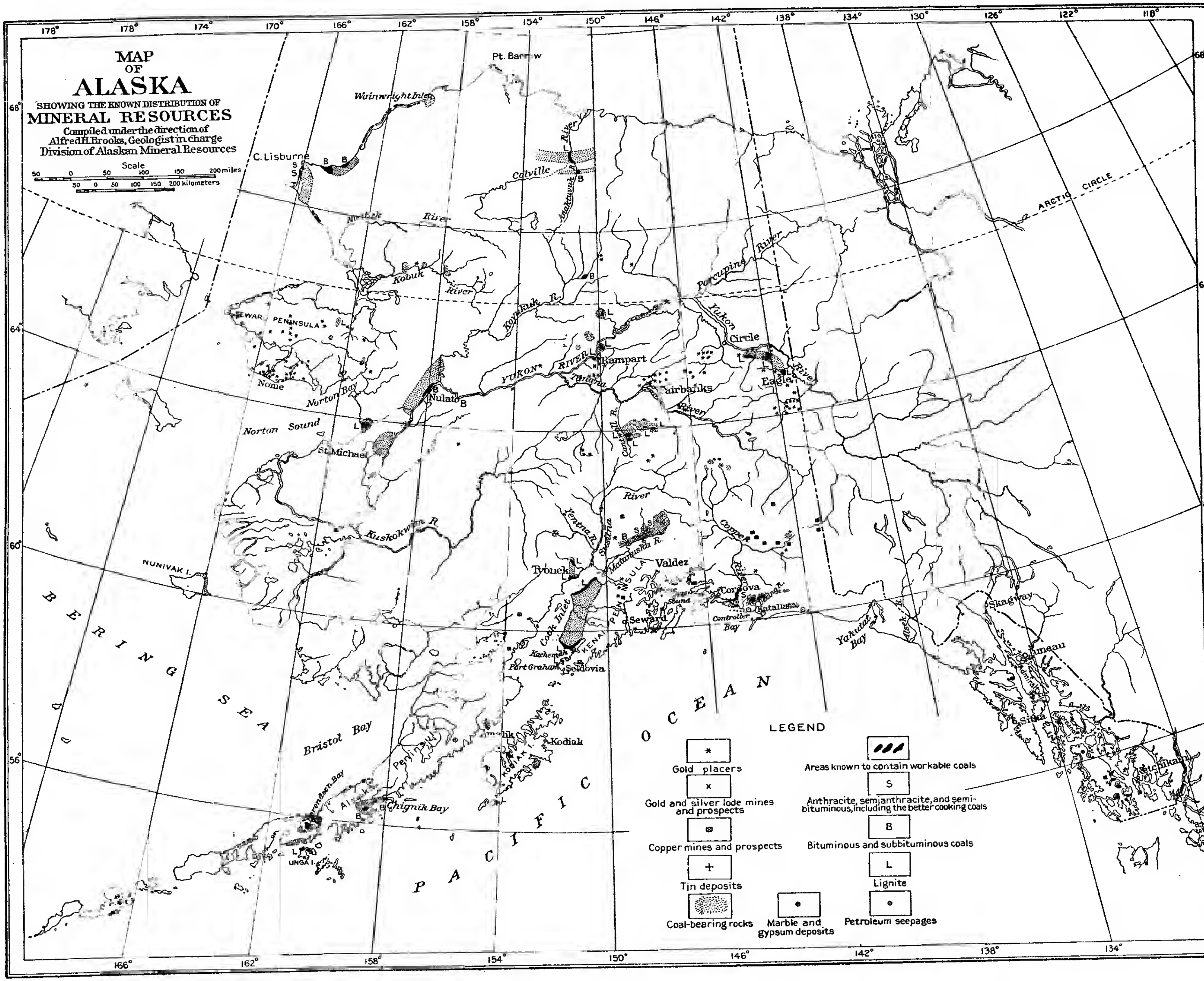
By Alfred H. Brooks,
Geologist in charge, Division of Alaskan Mineral Resources, United States Geological Survey.

INTRODUCTION.

A complete description of the mineral resources of any region is possible only when its geology has been exhaustively studied, and even then any quantitative determination of the mineral reserves is often little more than a bold guess. The Alaskan geologic surveys and investigations, begun a decade ago, now cover but 16 per cent of the entire Territory. These, moreover, for the most part have been of a preliminary character, and, while they have yielded important facts regarding the occurrence and distribution of the mineral deposits, they do not furnish the minute knowledge essential to quantitative determination. Detailed surveys and studies such as have been relied on elsewhere for quantitative data on mineral deposits are in Alaska almost entirely lacking, since less than a third of 1 per cent of its area has been subjected to such investigation. Therefore, as 84 per cent of the Territory is geologically almost unknown and less than 1 per cent has been mapped in detail, it will be evident that this statement can be only of a very general character.

The following account of the mineral resources of Alaska is based entirely on the work of the United States Geological Survey, whose reports furnish almost the only sources of information on this subject. In the preparation of this statement the writer has utilized the results of all the geologists and engineers who have worked in this field, and has received valuable assistance from G. C. Martin, C. W. Wright, L. M. Prindle, F. J. Katz, U. S. Grant, C. C. Covert, F. F. Henshaw, P. S. Smith, F. H. Moffit, and Adolph Knopf.

In the lack of comprehensive quantitative data it will probably best serve the purposes of this report to consider the more general problems of geographic and geologic occurrence of the various useful minerals of the Territory. The coal resources will be considered at some length, both because of the importance of the mineral fuel reserves and because the geologic occurrence of coal is such as to permit a quantitative interpretation of the data with a far greater degree of assurance than of those relating to other mineral deposits. The subject of iron ore reserves, of almost equal importance with that of coal, can be but briefly touched upon, because so few facts regarding it are available. But little attention has been devoted to iron ore


MAP OF ALASKA
SHOWING THE KNOWN DISTRIBUTION OF MINERAL RESOURCES
Compiled under the direction of Alfred H. Brooks, Geologist in charge Division of Alaskan Mineral Resources
Scale
50 0 50 100 150 200 miles
50 0 50 100 150 200 kilometers
LEGEND
Gold placers
Gold and silver lode mines and prospects
Copper mines and prospects
Tin deposits
Coal-bearing rocks
Marble and gypsum deposits
Areas known to contain workable coals
Anthracite, semianthracite, and semi-bituminous, including the better cooking coals
Bituminous and subbituminous coals
Lignite
Petroleum seepages
ARCTIC CIRCLE
BERING SEA
PACIFIC OCEAN
Pt. Barrow
Wainwright Inlet
C. Lisburne
Colville
Porcupine River
Yukon
Circle
Eagle
Rampart
Fairbanks
Nulato
Nome
Norton Bay
Norton Sound
St. Michael
Kuskokwim R.
Kobuk River
Koyukuk R.
Yentna R.
Susitna
Matanuska R.
Tyonek
Valdez
Cordova
Katalla
Controller Bay
Seward
Cook Inlet
Kachemak
Port Graham
Seldovia
Kodiak
Bristol Bay
Chignik Bay
Yakutat Bay
Skagway
Juneau
Admiralty
Sitka
Ketchikan
NUNIVAK I.
UNGA I.

by the Alaskan geologists, for there is not a single iron mine in the Territory and at only two localities have iron-ore bodies been prospected. Relatively much more is known about the auriferous deposits, especially the placers, for here the observation of the geologist is supplemented by the many facts developed in the course of mining and prospecting. But the character of these deposits, especially that of the auriferous lodes, makes estimates of mineral reserves of but little value. The same holds true of the copper deposits, which are of too great irregularity to allow even an approximation of the available tonnage. Moreover, though copper ores find a wide distribution in the Territory, they have been mined in only two districts. Most of the copper mines are not over 200 feet in depth, one only having reached 600 feet. Predictions as to permanency of ore bodies at depth in this field, which must form an important element in estimating tonnage, can therefore have no great value.

GENERAL DISTRIBUTION.

The ores and other minerals mined in Alaska up to the close of the year 1907 include gold, silver, copper, lead, tin, coal, petroleum, gypsum, marble, and mineral waters. In addition to these iron, tungsten, antimony, quicksilver, graphite, and peat have been found in deposits that will probably be exploited in the future. Of these only the deposits of gold, silver, copper, lead, iron, coal, petroleum, and peat will be described in this report.

As there are no political subdivisions of Alaska, it will be desirable to refer the distribution of its resources to certain geographic provinces, and these must first be defined. (See Pl. I.) The Pacific province includes the lode and placer districts of southeastern Alaska, the Controller Bay coal and petroleum fields, the copper lodes of Prince William Sound, the copper-bearing lodes and gold placers of the Copper River region, the gold placers and lodes and coal fields of the Susitna and Matanuska basins and of the Kenai Peninsula, and the coal fields and gold and copper lodes of the Alaska Peninsula and adjacent islands, often called southwestern Alaska. This whole coast province is a region of strong relief, and much of it is readily accessible from the waters of the Pacific, open to navigation throughout the year.

The mountain system included within the Pacific province forms a high barrier between the coast and the central province, which is of lesser relief. This central province, drained to Bering Sea by the Yukon, Kuskokwim, and some smaller rivers, includes the gold placers of the Yukon-Tanana region, the Koyukuk, and some smaller districts, as well as extensive deposits of lignitic coal. It is accessible in summer by river steamers, but in winter only by long sled journeys.

Seward Peninsula, forming a distinct province, embraces valuable gold placers, as well as some auriferous and argentiferous lodes, some tin deposits, and a little lignitic coal. It is accessible by steamer only during the summer months.

Northern Alaska is here made to include the high mountains which bound the central province on the north, as well as the region of lesser relief bordering the Arctic Ocean. This field has been but little explored, but it is known to contain some placer gold and bituminous as well as lignitic coal. It seems probable that further surveys will show the presence of extensive coal fields in northern Alaska.

These geographic subdivisions have an important influence on the question of the conservation of the mineral wealth of the Territory, for as the geographic conditions dominate the commercial exploitation of the resources, they determine in a large measure the rapidity with which these resources will become exhausted. For example, the lode deposits and coal fields readily accessible from the Pacific seaboard are being exploited for the use of the present generation. On the other hand, though the development of the placer fields of the central province began nearly a generation ago, large areas are still entirely unprospected, and the coal fields of the same region are almost entirely untouched. The coal fields of northern Alaska are not only entirely undeveloped, but are certain to remain so until the time in the future when the accessible coal of Alaska and the United States approaches exhaustion.

COAL.

[By Alfred H. Brooks and George C. Martin.]

STRATIGRAPHIC POSITION AND COMPOSITION.

The Alaskan coals include lignitic, bituminous (some of which will make good coke), and anthracite varieties. Of these the lignitic and lower-grade bituminous coals are the most widely distributed and, so far as now known, the most abundant, at least half of the known coals being lignites. To offset their lower fuel value the lignites often occur in thick beds and with a large percentage of coal in any given section. Moreover, their geographic distribution is such that they afford an important source of fuel for local consumption in some of the less accessible parts of the Territory.

These coals belong to four geologic periods, namely, Tertiary, Cretaceous, Jurassic, and Carboniferous. In addition to these there are some inferior lignites of Quaternary age, and it is by no means improbable that further investigation may lead to the discovery of coal at still other horizons. Of these four periods only the fuels of the first three promise to have any considerable commercial importance, and all but one of the important coal fields are of Upper Cretaceous or Tertiary age. In fact, a large part of the coal beds have been identified as belonging to the Kenai formation, whose age is believed to be upper Eocene. The Carboniferous and Jurassic coals vary in composition from semibituminous to subbituminous fuel. In the younger coal fields anthracite, various grades of bituminous, and lignitic coals are found.

The following table shows the composition of the coals from different parts of the Territory:

Analyses of Alaska coal.

[Compiled from reports of United States Geological Survey.]

District and kind of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Fuel ratio.
ANTHRACITE.						
1. Bering River, average of 7 analyses	7.88	6.15	78.23	7.74	1.30	12.86
2. Matanuska River, 1 sample	2.55	7.08	84.32	6.05	.57	11.90
SEMIANTHRACITE.						
3. Bering River, average of 11 analyses	5.80	8.87	76.06	9.27	1.08	8.77
SEMIBITUMINOUS.						
4. Bering River, coking coal, average of 28 analyses	4.18	14.00	72.42	9.39	1.73	5.28
5. Cape Lisburne, average of 3 analyses	3.66	17.47	75.95	2.92	.96	4.46
6. Matanuska River, coking coal, average of 16 analyses	2.71	20.23	65.39	11.60	.57	3.23
BITUMINOUS.						
7. Lower Yukon, average of 11 analyses	4.68	31.14	56.62	7.56	.48	1.90
SUBBITUMINOUS.						
8. Matanuska River, average of 4 analyses	6.56	35.43	49.44	8.57	.37	1.40
9. Koyukuk River, 1 sample	4.47	34.32	48.26	12.95	....	1.40
10. Nation River, 1 sample	1.39	40.02	55.55	3.04	2.98	1.39
11. Alaska Peninsula, average of 5 analyses	2.34	38.68	49.75	9.22	1.07	1.30
12. Cape Lisburne, average of 11 analyses	9.35	38.01	47.19	5.45	.35	1.24
13. Anaktuvuk River, 1 sample	6.85	36.39	43.38	13.38	.54	1.20
LIGNITE.						
14. Port Graham, 1 sample	16.87	37.48	39.12	6.53	.39	1.04
15. Southeastern Alaska, average of 5 samples	1.97	37.84	35.18	24.23	.57	1.02
16. Wainwright Inlet, 1 sample	10.65	42.99	42.94	3.42	.62	1.00
17. Colville River, 1 sample	11.50	30.33	30.27	27.90	.50	1.00
18. Upper Yukon, Canadian, average of 13 analyses	13.08	39.88	39.28	7.72	1.26	.99
19. Upper Yukon, Circle province, average of 3 analyses	10.45	41.81	40.49	7.27	1.30	.97
20. Upper Yukon, Rampart province, average of 6 analyses	11.42	41.15	36.95	10.48	.33	.91
21. Seward Peninsula, 1 sample	24.92	38.15	33.58	3.35	.68	.88
22. Chitistone River, 1 sample	1.65	51.50	40.75	6.10	....	.79
23. Kachemak Bay, average of 6 analyses	19.85	40.48	30.99	8.68	.35	.77
24. Nenana River, 1 sample	13.02	48.81	32.40	5.77	.16	.66
25. Kodiak Island, 1 sample	12.31	51.48	33.80	2.41	.17	.66
26. Unga Island, average of 2 analyses	10.92	53.36	28.25	7.47	1.36	.62
27. Tyonek, average of 4 analyses	8.35	54.20	30.92	6.53	.38	.58
28. Chistochina River, 1 sample	15.91	60.35	19.46	4.28	....	.32

DISTRIBUTION AND AREA.

The known coal-bearing areas aggregate some 1,202 square miles, while the estimated areas of the coal fields are 12,667 square miles (see p. 581). The distribution of the coal, together with a symbol indicating its quality, is shown on the accompanying map.

Besides showing the actual distribution of the areas believed to be underlain by workable coal beds (marked in black) the map also shows the areas of the coal fields, so far as they are known (marked by stippling). The difference in what is represented by these two symbols is that in the first are included areas in which there is a reasonable degree of certainty that commercial coal beds can be opened up, while the second indicates what is known of the probable extension of the coal fields, and hence defines the areas worthy of prospecting. It should be noted that this mapping does not by any means have the same value throughout the territory, for in some instances it is based on geologic surveys of a high degree of refinement; in others the data include only observations made during a rapid reconnaissance.

The coal fields can be considered under the three general geographic provinces already described: (1) The Pacific slope, (2) the central region, and (3) the northern region. (See map.) In the first are included the lignitic and bituminous fields of southeastern Alaska, Cook Inlet, the Susitna Basin, and the Alaska Peninsula, as well as the high-grade fuels of the Controller Bay and Matanuska regions. About 40 per cent, both of the area known to be underlain by coal and of the estimated area of the total coal fields of the Territory, falls in this province. It includes also at least 90 per cent of the known bituminous and higher-grade coals of the Territory. In considering this percentage of total coal area it must be remembered that this is the best-known part of the Territory, and there is, therefore, less likelihood of future discoveries of coal than in the less explored districts of central and northern Alaska. However, as over 50 per cent of this province is geologically almost unknown, there are possibilities that future surveys may lead to the discovery of more extensive coal-bearing areas.

The central province includes some bituminous and subbituminous coals on the lower Yukon, besides more extensive lignitic coal-bearing fields in the upper Yukon basin, near the coast line of Bering Sea, and elsewhere. Thirty-five per cent of the total known coal-bearing area falls in this province, and about 36 per cent of the estimated coal fields. At least 80 per cent of the central province, however, is almost unknown, so it is likely that further discoveries of coal will there be made.

The northern region includes the bituminous and subbituminous coals of the Cape Lisburne region, as well as lignitic and bituminous coal-bearing rocks in the Colville basin. These fields aggregate 24 per cent of the coal area of the Territory, and the area known to be underlain by coal forms 25 per cent of the total. This is a remarkable showing, in view of the fact that only about 10 per cent of this province has been studied geologically. There is every reason to believe that there are extensive coal fields in this part of Alaska.

THE COAL FIELDS.

SOUTHEASTERN ALASKA.

Though Tertiary (or possibly Upper Cretaceous) coal-bearing rocks are known to cover a considerable area on the southern part of Admiralty Island and on adjacent islands, the included coal beds have only a remote fuel value. The beds are from a few inches to 2 or 3 feet in thickness, and the coal, so far as known, is of a low-grade lignitic character.

BERING RIVER.

One of the two fields containing the largest known amount of high-grade coal lies about 25 miles northeast of the small indentation of the southern shore line of Alaska called Controller Bay. The field is drained by Bering River, from which it received its name. This

Bering River field embraces 21.6 square miles underlain by anthracite and 22.7 square miles underlain by semibituminous and semianthracite coal. The coal-bearing rocks trend to the northeast into the unsurveyed high ranges, and it is quite probable that there are considerable areas in the unsurveyed extension of the coal field or possibly other coal fields beyond the one surveyed.

The workable coal beds in this field vary from 6 to 25 feet in thickness, though local swellings occur, giving a much higher maximum. They are included in a great series of sandstones and shale of Tertiary age (Miocene?) which are closely folded and faulted. In quality the coals vary from an anthracite, with 84 per cent of fixed carbon, to a semibituminous, with 74 per cent of fixed carbon (see p. 571). The field includes some coking coal. There is no good harbor at Controller Bay, though plans have been made for building a breakwater. Another scheme of obtaining access to the coal is by constructing a railway from Cordova Bay, a good harbor lying 100 miles to the west. This railway is now (1908) about half completed.

COOK INLET.

Lignite-bearing Tertiary rocks occur widely distributed in the Cook Inlet region. These are usually little disturbed, but locally are considerably folded and faulted. The largest areas of coal-bearing rocks in this field occupy the western part of the Kenai Peninsula and are in pare buried under a cover of Quaternary gravels. It is not impossible that the entire Cook Inlet depression may be underlain by the coal-bearing formations.

The best-known part of this field lies adjacent to Kachemak Bay on the north, where 2,000 to 3,000 feet of coal-bearing rocks are exposed. These contain an aggregate thickness of over 60 feet of workable coal beds, the thickest of which is about 7 feet. Lignite in workable seams has also been found at Port Graham and Tyonek.

Though the Kenai Peninsula was the scene of the earliest (1854) coal-mining venture in Alaska, the output has been only a few thousand tons. These coals, in spite of their accessibility to tide water, can probably not compete with the higher-grade fuels, such as those of the Matanuska field. It seems probable that the coal reserves in the Cook Inlet region are very large, for the area of the coal field is estimated at 2,565 square miles.

MATANUSKA REGION.

The Matanuska coal field shares with that of Bering River the preeminence in the present fuel situation in the Territory. This field lies about 25 miles from tide water at Knik Arm, a northerly embayment of Cook Inlet. As, however, Cook Inlet is frozen during the winter months, the distance to tide water must be measured to the eastern side of Kenai Peninsula, about 150 miles.

The known commercially valuable coals of the Matanuska are included in folded and faulted rocks of Tertiary (Eocene?) age, including shales, sandstones, and conglomerates aggregating 3,000 feet in thickness. The coal-bearing series has been traced for 50 to 60 miles along the Matanuska Valley, but much of it is buried under a heavy blanket of Quaternary gravels. At the western end of the district the bituminous coal, which seems to form the main body of the field, appears to pass into a lignite, while there is some evidence that the same coal is represented by an anthracite at the eastern end of the belt. This anthracite may, however, belong to an older coal-bearing formation.

The commercial coals of the Matanuska field vary from a subbituminous to a semibituminous. There is also some anthracite, but of this less is known. It is evident from the facts in hand that there is a large amount of high-grade bituminous coal in this district. The beds vary from 5 to 30 feet in thickness.

So far as at present known, the total area underlain by commercial seams aggregates 46.5 square miles. As, however, much of the field is covered by gravels and as it has not been surveyed in detail, the coal-bearing area may be much larger. The total area of what may prove to be coal-bearing rocks is approximated at 900 square miles.

A railway is under construction which will lead to the opening of this field. This will bring about the development of the high-grade fuels, of which there is a large quantity. The lignites lying to the west of the Matanuska field will not now bear shipment until the coals of the higher fuel value approach exhaustion. As there is believed to be a very large amount of lignitic coal in this general province, it will be an important element of the ultimate fuel reserves of the Territory.

ALASKA PENINSULA REGION.

The widely distributed coal of the Alaska Peninsula and adjacent islands is in part of Cretaceous and in part of Tertiary (Eocene) age. It is chiefly lignite, but some good bituminous coals occur in this field. The rocks in which the coal beds occur are gently folded and locally, at least, considerably faulted. The total area of the coal fields of this province is estimated at 980 square miles, while that known to be underlain by coal is 61 square miles. About one-half of the coal-bearing area and about one-third of the probable coal field is lignitic, the balance varying from subbituminous to bituminous in quality. Coal has been mined in this field at Chignik and Herendeen bays and on the island of Unga for local use, but the total output has been only a few thousand tons. These coal fields are all readily accessible from good harbors and will form one of the early available fuel assets of the Territory when the demand for coals of this grade warrants their exploitation.

YUKON REGION.

The coals of the Yukon, including bituminous and subbituminous, together with a large amount of lignite, are for the most part of Tertiary (Eocene?) age. Some of the bituminous may, however, be of Upper Cretaceous age. The Tertiary lignitic coal beds typically occur in association with conglomerates, sandstones, and shales, usually only little deformed, but sometimes profoundly folded and faulted. The bituminous coals, which are confined to the lower Yukon, occur with finer sediments, which have been gently folded and somewhat faulted.

The lignitic coal beds occur up to 20 feet in thickness, the bituminous in beds from 2 to 3 feet. These comparatively thin seams have not encouraged exploitation, in spite of the high price of mineral fuel in this central region, but a small production has been made for the use of the Yukon River steamers.

Coal-bearing beds are so widely distributed in the Yukon region that it will not be feasible to give an account of all the occurrences. The three largest fields are (1) Nulato region, (2) Nenana region of the lower Tanana Valley, (3) Washington and Coal Creek belt of the upper Yukon. Of these the Nulato field contains the best coal, while the Nenana is the most extensive and has the thickest beds. The total area known to be underlain by coal in the entire region is 264 square miles, while the coal fields may embrace 2,000 square miles or more.

These Yukon coals will have a high value for local use when the scant supply of accessible timber has been exhausted. There is a constantly increasing demand for power in the placer districts, and this can be met only by developing the water powers, which are not extensive, or by utilizing the coals. The low fuel values and the difficulties of transportation of these coals will probably lead to their local transformation into electric power, to be transmitted to the mining camps. The location of some of the lignite fields with reference to the placer fields is well suited for this purpose.

That a large amount of lignite in excess of any future local demand that can now be foreseen occurs in the Yukon region can not be denied. So far as exportation is concerned, it is certain that the low fuel value of these coals and their inaccessibility will lead to their conservation until the fuel supply of other regions approaches exhaustion.

SEWARD PENINSULA.

The known coal-bearing areas of Seward Peninsula do not exceed a few square miles, and the quality of the coal is of a low grade. This coal, however, is worthy of mention, because it can probably be locally utilized to furnish power for mining purposes, and hence conserve the higher-grade coals which are now being brought in from outside sources. This appears to be a good example of the way a local supply of lignite may reduce the consumption of higher grade fuels. Its success will depend on the development of economical means of utilization of these low-grade fuels, so as to bring them within the sphere of commercial practice and permit their substitution for higher-grade fuels transported from a distance.

NORTHERN ALASKA.

Geographically, the known coal fields of northern Alaska fall into three groups: (1) Cape Lisburne, (2) the Colville Valley, (3) Wainwright Inlet. Coal has also been reported to occur between these areas, as well as east of the Colville River. The Cape Lisburne field includes the Corwin and Cape Beaufort districts.

Three coal-bearing formations are recognized in this northern field: (1) lower Carboniferous (Lisburne formation), made up of slates, shales, and limestones, with some high-grade bituminous coals, and having a thickness of 500+ feet; (2) Jurassic (Corwin formation), including at least 15,000 feet of shales, sandstones, and conglomerates and containing a large number of subbituminous coal beds; (3) Tertiary (Kenai formation?), made up of conglomerates, sandstones, and shales, with lignitic coal seams. The two lower formations are considerably folded, but the Tertiary beds are, as a rule, only little disturbed.

The total area known to be underlain by coal aggregates 302 square miles, while the coal fields, roughly outlined from the data in hand, include some 3,000 square miles. The scant evidence at hand points to the conclusion that a survey of this northern region will show very large coal fields in this part of Alaska.

A little mining of coal for local use has been done in the bituminous field near Cape Lisburne and in the lignitic field of Wainwright Inlet, but the region as a whole is practically untouched. It is certain that there will be no extensive mining in this northern field for a generation or two to come. These coals are too inaccessible to invite exploration, either under the present demands or any that can now be foreseen.

THE COAL RESERVES.

INTRODUCTION.

It will be evident from the facts presented that there are few data on which even an approximate idea of the available tonnage of Alaskan coal can be based. Of the 1,238 square miles believed to be underlain by coal, less than one-quarter has been surveyed in sufficient detail to yield any quantitative data whatever. Even where such surveys have been made, a large factor of uncertainty is introduced either by the folded and faulted condition of the coal beds, which exists in some fields, or by the lack of definite knowledge of the continuity of the coal beds in others. There must, therefore, be a very large element of uncertainty in the tonnage estimates of the 300 to 400 square miles of surveyed coal fields. Moreover, in Alaska there are practically no available data from private sources, such as the results of extensive mining or prospecting operations, which have formed an important element in the estimates made of the mineral resources in the States.

The estimates of tonnage to follow were made on the following basis:

1. No beds less than 3 feet thick were assumed to be workable or contributed to the tonnage.
2. The depth of workability was assumed to be 3,000 feet in the case of the highest-grade coal (anthracite, semianthracite, semibituminous), 2,000 feet in case of the better bituminous and subbituminous coals, such as those on the lower Yukon and at Cape Lisburne and on the Matanuska River, and 1,000 feet in the case of the poorer subbituminous and all the lignites.
3. The tonnage was computed by the following formula: Tonnage = area of bed to limit of workability (square miles) × thickness (inches) × sp. gr. × 72,600.
4. The specific gravity was assumed to be 1.30 for lignite, 1.35 for bituminous, and 1.38 for the high-grade coals.
5. Bering River field: A certain percentage of the coal-bearing rocks is shown by the average sections to consist of workable coal beds. This percentage of the computed bulk of rock to limit of workability gave the estimated tonnage.
6. Nenana coal field: As for Bering River, with the necessary change for percentage of coal in rocks.

7. Matanuska coal field: Each bed was estimated separately according to its average thickness, length, according to a safe assumption of continuity, and width on the dip to the limit of workable depth.

8. Lisburne fields: The Corwin district was computed like the Matanuska, length of beds being assumed to be the distance from the shore to the edge of the area colored on Collier's map. The Beaufort district was assumed to have one-half the tonnage per square mile of the Corwin district.

9. Yukon field: Each bed figured as in Matanuska, but the beds were not assumed to extend in any case more than 1 mile in each direction from the mine or prospect where they had been exposed, except in the Washington-Bonanza district, where a continuity of 50 miles on the strike was assumed.

10. Cook Inlet field: Computed as for the Matanuska.

All the other fields were estimated on the basis of a most conservative estimate of thickness of coal underlying the field and an area believed to be a safe minimum. Neither in this case nor in any of the others was the coal assumed to go beyond where we have reliable information from members of the Survey concerning it. The areas used in making the last class of estimates are consequently very small and are subject to a possible immense extension in the light of subsequent work.

Estimate of tonnage and areas, Alaska coal fields.

	Tonnage.	Areas believed to be underlain by coal.	Supposed areas of coal fields.
	Short tons.	*Sq. miles.*	*Sq. miles.*
Anthracite, Pacific coast	1,611,700,000	25.8	....
Semianthracite, Pacific coast	517,100,000	7.2	....
Semibituminous:			
Pacific coast	1,425,800,000	35.8	....
Arctic slope	66,800,000	14.2	....
Total semibituminous	1,492,600,000	50.0	....
Total high-grade	3,621,400,000	83.0	620
Bituminous:			
Pacific coast	2,600,000	2.0	900
Interior region	15,900,000	162.0	2,475
Total bituminous	18,500,000	164.0	3,375
Subbituminous:			
Paific coast	535,500,000	49.7	657
Interior region	59,200,000	6.0	15
Arcctic slope	3,465,600,000	205.0	1,323
Total subbituminous	4,060,300,000	260.7	1,995
Lignite:			
Pacific coast	2,173,100,000	337.0	2,938
Interior region	4,228,000,000	264.5	2,003
Arctic slope	1,003,200,000	93.0	1,736
Total lignite	7,404,300,000	694.5	6,677
Summary by provinces:			
Pacific coast	6,265,800,000	457.5	5,115
Interior region	4,303,100,000	432.5	4,493
Arctic slope	4,535,600,000	312.2	3,059
Grand total	15,104,500,000	1,202.2	12,667

The incompleteness of these figures can best be illustrated by some examples. The Bering River field may be extended into the mountains and have many times its present known area. If the entire eastern and western extensions of the Matanuska Valley are underlain by coal beds, as may be the case, it will increase the tonnage of this field many times that used in the present estimate. In the Cook Inlet and Susitna regions the estimates for tonnage are based on a coal field of 30 to 40 square miles. As a matter of fact, it is not improbable that the whole Cook Inlet-Susitna depression may be underlain by coal-bearing rocks at no depth prohibitive of mining. If this is the case, this coal field might embrace 10,000 to 20,000 square miles.

In view of these facts, it is perhaps conservative to multiply the above figures by 10 or even by 100 to arrive at an approximation of the fuel reserves of this vast unexplored region. This is especially true of the lignite reserves, for there are known to be very extensive fields of low-grade coals in Alaska.

PRODUCTION AND CONSUMPTION.

Though an attempt at mining coal on Cook Inlet in 1854 by the Russians was the first mining undertaken in the Territory, yet the total output up to the present time has been very small, as indicated in the following table. In 1907 there were four productive coal mines in Alaska.

Production of coal in Alaska, 1888–1907.

Year.	Short tons.	Value.	Year.	Short tons.	Value.
1888–1896 [a]	6,000	$84,000	1903	1,447	$9,782
1897	2,000	28,000	1904	1,694	7,225
1898	1,000	14,000	1905	3,774	13,250
1899	1,200	16,800	1906	5,541	17,974
1900	1,200	16,800	1907	10,139	53,600
1901	1,300	15,600			
1902	2,212	19,048	Total	37,507	296,079

[a] The production for 1888–1896 is estimated on the best data obtainable. That for the years subsequent to 1896 is based for the most part on data supplied by operators.

The smallness of the output is chiefly due to two reasons: First, because up to a decade ago, when the rapid advancement of the gold-mining industry began, the local demand for coal was very small, being confined to that of the canneries and shipping interests and the Treadwell mine, which could be supplied at low cost by the fuels brought from Vancouver Island or Washington. Second, the existence of extensive bodies of high-grade coal in Alaska, geographically situated so that it could be exported, has been generally known only for a few years. Since the discovery and surveys of the Controller Bay and Matanuska regions there has been much activity looking to the development of these two fields. As, however, the marketing of this coal requires the construction of 150 miles of railway in one field and 100 miles of railway or 25 miles of railway and possibly an expensive breakwater in the other, the progress of exploitation is necessarily slow. Moreover, the uncertainty of obtaining title to coal lands, which still exists, has made capitalists rather guarded in furnishing the money necessary for these enterprises.

Though the Territory has produced annually only a few thousand tons, the consumption of coal during the past decade has rapidly increased. The following table presents the available statistics regarding consumption of mineral fuels in Alaska:

Shipments of coal and coke to Alaska, July 1, 1903, to June 30, 1907.[a]

	Twelve months ending June 30—							
	1904.		1905.		1906.		1907.	
	Quantity.	Value.[b]	Quantity.	Value.[b]	Quantity.	Value.[b]	Quantity.	Value.[b]
	Long tons.		*Long tons.*		*Long tons.*		*Long tons.*	
Domestic anthracite			5	$85			476	$7,090
Domestic bituminous	41,704	$193,740	42,245	187,352	67,293	$265,047	48,383	270,651
Domestic coke	392	2,251	478	4,281	346	3,676	3,108	25,629
Foreign anthracite			10	148	304	1,836	25	216
Canadian bituminous	63,652	261,987	59,272	260,110	41,481	187,312	64,029	287,948
Australian bituminous	1,609	4,303					3,529	8,587
Japanese bituminous							11,546	33,789
Foreign bituminous, shipped via United States	3,324	23,904	5,550	29,673	706	4,838	4,141	28,679
Foreign coke					7,628	38,139	2,959	14,795
Total	110,681	486,185	107,580	481,657	117,758	500,848	138,196	677,384

[a] Commerce of the noncontiguous territory of the United States, Bureau of Statistics, 1904, 1905, 1906, 1907.

[b] At port of shipment.

Shipments of petroleum to Alaska.[a]

Period.	Crude petroleum.			Naphthas.	
	Gallons.	Barrels.	Value.	Gallons.	Value.
Six months ending—					
December, 1902	21,000	500	$390	60,358	$12,186
June, 1903	840,000	20,000	28,000	210,147	33,831
December, 1903	1,008,000	24,000	36,000	84,776	18,054
June, 1904	1,008,400	24,010	35,823	231,658	43,814
December, 1904	1,008,030	24,001	33,603	106,623	23,904
June, 1905	1,780,326	42,389	59,204	499,196	75,187
December, 1905	935,060	22,263	31,864	214,300	34,734
June, 1906	1,428,000	34,002	20,400	361,681	60,214
December, 1906	1,260,100	30,000	18,009	219,297	40,480
June, 1907	2,545,200	60,600	36,360	354,210	59,012
December, 1907	6,558,500	156,155	107,146	282,671	60,333
June, 1908	3,852,940	91,736	55,482	599,959	91,084

[a] Monthly Summary of Commerce and Finance, Bureau of Statistics, 1902–1906.

SUMMARY AND CONCLUSIONS.

The advancement of copper and gold mining, construction of railways, etc., will cause a constantly increasing consumption of coal. It would appear to be in accord with a policy of conservation of mineral fuels to meet this demand from the local supply. Every ton of coal or barrel of petroleum shipped to Alaska by steamer or rail entails a certain amount of fuel consumption for transportation. Moreover, this long carriage is commercially possible only for high-grade fuels, while for local consumption the large supply of lignites of lesser fuel value can be utilized. For example, many of the Alaskan river steamers, now using California petroleum as fuel, could be supplied by the local lignites. This would prevent a double waste: (1) The more valuable fuel is consumed instead of the more abundant lignite, and (2) as the petroleum is brought nearly 4,000 miles by steamer, fuel is used for its transportation. The utilizing of the coals in the Yukon region as a substitute for wood would also conserve the scant supply of timber.

Again, the use of the local coking coals for the reduction of the copper ores will effect a saving of mineral fuels. At present the copper ore is shipped a distance of 500 to 1,500 miles, while if it were smelted near its locality of production 70 to 90 per cent of the material could be left behind, with a corresponding saving of fuel used in transportation. Another saving would be brought about in the case of Alaska steamers now carrying coal from the southern ports for the round trip, if the local fuels were utilized for the return journey.

Discussion of the future utilization and conservation of Alaska's coal supply can best be made by considering separately the same three geographic provinces under which the coal fields have been described: (1) The Pacific slope, (2) the central regions, (3) the northern region. These will here be considered in the reverse order in which they have been given.

The northern coal fields lie in a region tributary to the Arctic Ocean, which is locked in the ice for all but two or three months in the year. Some lie close to the seaboard; others far inland. While little is known of the fuels of this region, all the facts available point to the conclusion that this province contains very extensive coal fields. These mineral fuels are in a region where there are practically no industries and with little promise that any will be developed and the coals are unavailable until the more accessible mineral fuel supply of the world approaches exhaustion. To bring them to a harbor open throughout the year would mean the construction of at least 1,000 miles of railway. Such a haulage, leaving out all other considerations, is of course prohibitive for any present fuel demand. Moreover, these coals are not needed, nor likely ever to be, for any local use, except some of those at Cape Lisburne, which may be utilized for local shipping, and some others which may be used by the scant Eskimo population, now that the supply of driftwood is approaching exhaustion..

The fuels of this northern region can, therefore, be regarded as conserved by the geographic conditions until future generations may have to draw upon them. They can consequently, for the most part, without injury to any existing commercial interests and without retarding the development of the country, be placed under such legislative provisions as will permit their utilization only under such restrictions as the future conditions of the mining industry shall demand.

The coals of the central region are in part accessible to rivers navigable during the summer months and in part lie near the proposed railways from the Pacific to the Yukon. There also remains a considerable percentage but little more available to the present generation than the fuels of the northern fields. These coals are chiefly lignitic in character and, under no demand which can now be foreseen, could be utilized for export to other districts. To bring them to the States would require a railway haulage of 400 to 500 miles and then transportation by steamer for 1,000 to 1,500 miles in addition.

On the other hand, the development of these fields to supply the local demand will conserve (1) higher-grade fuels now imported from great distances and (2) local supply of timber. While little is known of the amount of coal available in this central province, there is every reason to believe that it is far beyond any local demand of the future.

The conservation of the coal of the Pacific slope province is a more complex problem, both because of the high grade of some of the fuels and of their greater accessibility. While none has yet been exported, the great demand for the high-grade bituminous and anthracite coals, such as are found in the Controller Bay and Matanuska regions along the Pacific coast, will lead to their exportation as soon as railways make them accessible. It is probable that the market for these coals will for a long time exceed the production, which will greatly stimulate mining activity once the transportation problem has been solved. When the coals are put on the market, they will probably curtail, if not entirely cut off, the demand for the lignitic and lower-grade bituminous coals which are so abundant in the Pacific coast province of Alaska. Therefore the production of the high-grade fuels will effectually conserve those of lesser fuel value for the present. Some of these low-grade fuels, however, are so accessible and so abundant that future demands and strong competition may lead to wasteful methods of mining, provided they are all permitted to pass into unrestricted private ownership.

The reserve of these anthracite and bituminous coals of the Pacific slope, while it can not now even be approximated, in all probability is far below that of the lignites. It seems probable that an extensive area of the high-grade fuels may be found among the high mountains and glaciers to the northeast of the present known limits of the Bering River field. If such be the case, this will be another locality where the geographic conditions will prevent mining until there is far more demand for the fuel than at present. In the Matanuska there is probably also a large quantity of coal under the Quaternary coating of gravel. Making allowances for future discoveries, however, the high-grade fuel is not abundant, considering the demand for it.

From the standpoint of conservation and economic utilization, the possibility of intense competition between the coal of the Bering and Matanuska fields and that of Puget Sound is the danger point in the prospective situation. If each field develops only to the extent of supplying the demand for the kind of coal which it best can furnish, then the immediate use of the coal will be legitimate and economical. But if the individual fields develop beyond the demand of their respective proper markets—if the Bering River field produces more than the needed supply for steamship, smithing, and local railway and smelting needs and of domestic anthracite, if the Matanuska produces more than is needed for its local railways and smelters, for bunker coal at its tidal terminus, and for shipment to the Pacific coast coke ovens, and if the coal from other fields invade these markets—there is sure to be ruinous competition, which may lead to cutting prices with the sole object of destroying all competition and establishing a general monopoly. In such ruinous competition as has existed in some of the eastern fields the coal fields will be robbed of the more cheaply minable coal at the cost of the destruction of larger amounts which will be left in the ground so crushed and buried that it can never be recovered, coke for distant shipment will be made by wasteful processes at the mines instead of shipping the coal to points where both the coke and the by-products can be used, coal will be coked which would better be used for other purposes, and the waste by consumption en route will be extended to the Alaska coals.

If these high-grade fuels, some of which make excellent coke, are not exploited, several conditions will probably be brought about:

First. The west coast of the United States will probably continue to draw heavily on the fuels of British Columbia, Australia, and Japan, and to the amount imported will conserve its own supply.

Second. There will be an increasing demand for fuel oils, which, while it may not affect the production, will stimulate the search for new oil fields.

Third. The west coast will probably continue to rely on the East for its pig iron and steel, for in the absence of good cheap coke—except as Alaska can supply it or the processes of coking coals are improved—the local supplies of iron ore will not be utilized, unless, possibly, by electrical methods of smelting. As a concomitant to this, the iron ore and coking coals of the East, which are of the most value to the nation, being nearest the centers of the population, will be correspondingly diminished.

Fourth. What has been said of the relation these coals bear to the development of an iron industry on the Pacific coast is to a lesser extent true of copper smelting. Without the use of Alaska coke either the copper ores will be transported to British Columbia or Puget Sound or the coke will be brought to the copper deposits. In either case there is a loss in transportation. While it is true that these factors will affect the copper-mining industry and lead to the exploitation of only the richer deposits, yet the past few years have shown that it is economically possible to bring either the coke to the copper or the copper to the coke.

Fifth. Certain loss of fuel in transporting eastern coals to the west coast for certain purposes where their use is imperative will continue. This is, however, a small item, as the total tonnage of eastern coals to the West is insignificant.

Sixth. There will be no local supply of high-grade coals on the west coast for the use of the navy.

In considering the above facts it must be remembered that these Alaska bituminous and anthracite coal fields can be made accessible only by the expenditure of a very large amount of money. The millions of dollars necessary for the development of these fields will not be forthcoming unless provision be made by which a large tonnage of coal will be made available.

PEAT.

Peat is found in nearly every part of Alaska except in the high ranges. The humidity of the Pacific coastal zone and the consequent luxuriant vegetation favors the accumulation of peat. Southeastern Alaska is heavily forested and often has dense growth of underbrush with a flooring of moss. In southwestern Alaska timber is entirely absent, but all the lowland and much of the upland regions are covered with moss, grass, and small shrubbery. The prevailing humidity in both these districts favors the accumulation of vegetable refuse. Though there has been no prospecting for peat in this part of the Territory, deposits are known at least 15 to 20 feet in thickness and are believed to be of good quality.

Central and northern Alaska have a much smaller precipitation. Here, however, the soil is nearly everywhere mantled by a dense blanket of moss and other vegetation. This is especially striking in the extensive timberless areas or tundras which lie along Bering Sea and the Arctic Ocean. In these two provinces the subsoil is usually frozen, which retains the waters at the surface. The moss, except in excessively dry weather, is usually saturated with water. All these conditions, which promote vegetable growth and retard evaporation and oxidation, are favorable to the formation of peat. As a matter of fact, there is nearly everywhere a layer of peaty material underneath the soil. In some natural exposures peat deposits have been observed in these provinces having a depth of 30 to 40 feet. While the widespread surface layer of peat is of an inferior quality, some of the deeper-lying beds are probably of high grade. There are no data whatever at hand to estimate the available supply of peat. As, however, it is found in every part of the Territory and on the great tundras of the north, occupying at least a quarter of the Territory and comprising layers of greater or less thickness, the supply must be enormous and possibly exceeds that of the entire United States.

In the presence of more easily available fuel there has been no occasion to utilize any of the peat beds, so practically nothing is known of their fuel value, extent, or thickness, except what has been stated. Probably the only place in Alaska where this mineral fuel has been exploited is a peat bed saturated with petroleum residue, near Cold Bay, on the Alaska Peninsula, where the material has been used for fuel at the neighboring oil drills. Here, however, it is the petroleum residue rather than the peat which gives the deposit its chief value.

The peat deposits have at present no value, since lignitic and better-grade coals are too widely distributed to encourage the use of a less available fuel. The time appears also very remote when these peat deposits (except at localities where coal is absent) will be utilized. Certainly recourse to the peat will take place only when the more valuable mineral fuels are not obtainable.

PETROLEUM.

[By G. C. Martin.]

Petroleum may exist in the rocks at many places in Alaska, but at only four localities are the known indications sufficient to justify drilling. Wells have been drilled at three of these localities, but petroleum has been obtained in quantity at only one of them. In all of these the petroleum is of the high-grade variety, suitable for refining, like that from Pennsylvania. These four will be briefly described.

The Katalla field is situated near the mouth of Copper River, in latitude 60° north, longitude 144° west, or about 1,250 miles northwest of Seattle and 400 miles northwest of Sitka. The rocks in this field consist of Tertiary shale, sandstone, and conglomerate. The structure is complex, the rocks being steeply and intricately folded and cut by faults. These conditions would raise doubt concerning the existence of bodies of oil if it were not for the abundant seepages and the presence of oil in the wells. As it is, they increase the cost and other difficulties of drilling and make it entirely impossible to estimate the area of the probable oil-producing territory.

Sixteen wells have been drilled in the Katalla field. The result has been a moderate production of oil from one well and the demonstration of smaller quantities in three others. As only a small part of the area in which the presence of seepages suggests an oil field has been drilled, the proof of the existence of any considerable volume of oil is yet to be made.

The Cook Inlet oil fields are about 320 miles west of Controller Bay on the middle part of the west shore of Cook Inlet. Seepages are here numerous and prolific, but though several wells have been drilled, none has yet proved successful. This field is in an area of Jurassic rocks which are chiefly shales and sandstones. The folding is much more moderate than at Controller Bay, but many faults are present. The relation of the occurrence of oil to the geologic conditions has not been discovered, and hence the areas of possible oil-producing territory are entirely problematical.

At Cold Bay, on the Alaska Peninsula, 160 miles southwest of the Cook Inlet fields, there are many large seepages and several wells have been drilled, none of which has produced more than traces of oil. Here, as in the Cook Inlet field, the rocks are chiefly Jurassic shales and sandstones. The structural conditions are not unlike those on Cook Inlet.

Near Cape Yakataga, 75 miles east of Controller Bay, many large seepages are reported, but owing to the unaccessibility of the region no drilling has been attempted. These seepages are located on Miocene shale and sandstone which are steeply folded.

Summarizing, it may be said that the occurrence of oil is suggested under considerable areas in Alaska, but the presence of profitable oil pools has yet to be shown. The low price of oil on the Pacific coast and the high cost of drilling in Alaska make any attempt to develop the possible Alaska fields at present an unattractive proposition.

All considerations point to the desirability of conserving the Alaska fields until the decline of the California and Mid-Continent fields. When Alaska oil is utilized it should be for refining, and the burning of crude Alaska oil should be discouraged.

IRON ORES.

There being now practically no demand for iron ores on the west coast, such ores have not been sought for in Alaska. The only iron which has been found is that discovered incidentally in prospecting for other minerals, and thus far this has been chiefly magnetite, occurring at only a few localities along the Pacific seaboard. The following note on these deposits has been prepared by C. W. Wright:

Magnetite is the only iron ore that has been found in southeastern Alaska in commercial quantities. This ore occurs in large bodies, forming contact deposits along the contacts of diorite and limestone on Prince of Wales Island, where it is associated with the copper deposits, and occurring as magmatic segregations associated with basic intrusive rocks at several points along the mainland coast.

At the copper mines of Prince of Wales Island a considerable tonnage of magnetite carrying from one-half to 1½ per cent of copper has been developed which can not be profitably mined as a copper ore. However, if there were a market for the iron in these ores, the copper could be readily separated mechanically and the deposits mined with profit. The surface showings of magnetite in this copper district are very large, and the estimated tonnage, with a depth of only 30 feet, is about 3,000,000 tons of magnetite. There is, of course, a much greater amount of possible ore, concerning the extent of which almost nothing is known. These ores for the most part contain practically no phosphorus or detrimental impurities, and may be classed as Bessemer ore.

Explorations have been begun to develop magnetite deposits near Haines, on the mainland coast of Lynn Canal, but little is known as yet of their extent or the character of the ores.

U. S. Grant, in his study of the copper deposits of Prince William Sound, noted some hematite ores, but could not determine whether the ore was present in commercially valuable deposits. He also reports the occurrence of magnetite associated with pyrrhotite on Prince William Sound and with chalcopyrite near Seward, on the Kenai Peninsula. His investigations, on the whole, do not encourage the idea of the presence of workable iron ores in this district.

In the Iliamna Lake region there are some copper deposits which from accounts, appear to be of similar origin to those of Prince of Wales Island. With these is said to be associated a large amount of magnetite. So far as known, iron-ore bodies have been found at only one place in the interior. At this locality, which is near the head of the Nabesna River, there is a 2½-foot vein of magnetite which occurs in a limestone near the contact with an intrusive.

The conditions of occurrence of both types of southeastern Alaska magnetite deposits probably repeat themselves along other parts of the Pacific coast line, so that there is a probability that similar bodies of iron ore occur elsewhere. Though the evidence is very scant, it is not impossible that Alaska may have important iron-ore reserves.

GOLD.

INTRODUCTION.

Mr. Lindgren's general report on precious-metal resources of the United States, contained in this volume, emphasizes the fact that no definite statement of the gold reserves is possible. If this be true of the United States, it is far more so of a little-known region like Alaska, where the auriferous deposits have been found in widely distributed districts, usually separated by extensive areas, often but little prospected, sometimes almost unexplored. Moreover, except in southeastern Alaska, the auriferous deposits thus far developed are primarily those of the alluvium, and there has been little search for lodes. Therefore, in most of the gold-placer districts the possibilities of developing an auriferous lode-mining industry are almost unknown.

Geologic survey and investigation, when executed with sufficient thoroughness, lead to definite results concerning the distribution and occurrence of auriferous deposits. If a region has been mapped in detail, the geologist can outline with a fair degree of certainty those areas worth prospecting for gold. Such investigations, however, can be interpreted quantitatively only to a very limited degree in reference to placers and are practically worthless for the purpose of forecasting the gold content and reserves of undeveloped lode deposits.

The actual valuation of developed lode deposits can, of course, be carried only to the limits of the mine workings, which permit the blocking out and sampling of the ore bodies. Such an investigation can be made only at great cost and is properly the function of the mine owner and not the federal geologist.

Placer deposits, whose values are far more regular of distribution, admit of a rough valuation by the geologist; but even in the case of placers the quantitative determination of gold contents in any given body of gravel can be arrived at accurately only by extensive excavations are drilling, and by sampling. This also is evidently the function of the mine owner and not of the federal geologist. Most Alaska placer miners have done so little careful prospecting of their properties as to make their statements in regard to metal contents of but little service in estimating the placer gold reserves. Such data as are available have been carefully compiled by the Geological Survey, but while they may have value in forecasting the direction of future mining development, they are far too inexact and incomplete to admit of more than a bold guess at the gold reserves. Any estimate made at the present time can not take into account the latent possibilities of the hundreds of creeks which, though unprospected, are believed to lie within the gold-bearing area.

In the following account emphasis will be laid on the subject of general distribution and occurrence of the auriferous deposits, because it is believed that such data form the most important element in the valuation of these deposits. Given this information, together with a statement of past production, the technician at least is able to draw his own conclusions.

GEOLOGIC AND GEOGRAPHIC DISTRIBUTION.

The known gold deposits of Alaska can be grouped into three general types: (1) Gold occurs near the contacts between granitic or other igneous intrusions and altered sediments. (2) It occurs in metamorphic schists. (3) It occurs in association with Mesozoic or Tertiary volcanics. Nearly all of the auriferous lodes which have thus far been productive are of the first type, while the second appears to be typical of most of the important placer districts. Examples of the third type have been so far limited to only a few localities. There is some evidence to indicate that the source of the gold of the placers occurring in areas of schistose rocks may be in veins which bear a genetic relation to, as well as a close association with, igneous intrusives. If this proves to be generally the case, it may be found that the deposits assigned to the first two groups may be practically identical in origin.

Most of the auriferous deposits occur in rocks which have been more or less highly altered, but the metamorphism in the placer districts has usually been more pronounced than in lode districts. There are no considerable areas of metamorphic rocks known in Alaska which are not locally more or less auriferous, so that the distribution of these rocks is one of vital importance to this discussion. The metamorphic terranes vary in age from Cambrian or pre-Cambrian to Carboniferous and possibly Triassic. There are also some altered Cretaceous beds which are locally auriferous. While in Alaska their geologic age has little direct bearing on the question of the distribution of gold, yet the most important gold fields now developed are in regions where the rocks belong chiefly to lower Paleozoic or older terranes.

Three considerable belts of metamorphic rocks traverse the Territory. One of these skirts the Pacific seaboard, embracing the auriferous lode and placer districts of southeastern Alaska (see map, Pl. I), the Prince William Sound copper district, and some small gold-bearing areas lying in between. Its southwestward extension is found in the Kenai Peninsula and on Kodiak Island, where it includes some placer and lode deposits.

A second belt stretches southwest from the international boundary, near the famous Klondike district, and includes the Fortymile, Birch Creek, Fairbanks, and other gold placer-bearing areas. Its extension is probably to be sought in the little-explored region lying between the lower Yukon and the Kuskokwim, and may include the newly discovered placers of the Innoko Valley.

The third belt lies north of the main Yukon Valley, includes the gold placers of the Chandalar, Koyukuk, and Kobuk districts, and may find its continuation in the auriferous metamorphic rocks of Seward Peninsula.

In addition to these broad belts thus defined, there are some smaller areas in which gold has been found, such as those of the Nizina, of the Chistochina, of the Yentna, of the Bonnifield, and of the Kantishna districts. These, with others, which will not be enumerated, have yielded some placer gold.

SOUTHERN ALASKA.

The auriferous deposits of southeastern Alaska have been investigated by C. W. and F. E. Wright and A. C. Spencer, from whose reports the following data are drawn: This province is the one in which the close association of the metalliferous lodes with the intrusives is most strongly marked, and where this relation was first worked out. It appears that the strongest mineralization lies close to the western margin of the great intrusive masses of the Coast Range. Similar intrusives are, however, widely distributed in isolated stocks throughout the coastal region of this part of the Territory and its adjacent islands, and these, too, have been found to be mineralized at a number of localities. As there are hundreds of miles of these contacts, and as but few of them have been carefully prospected, the chances of finding additional auriferous lodes appear to be good. At the same time it should be noted that the mere fact of mineralization does not imply the existence of valuable deposits, and that, in spite of the fact that this part of Alaska has been the scene of active mining for nearly thirty years, only the Juneau district has furnished any considerable gold output, and this has chiefly come from the three mines of the Treadwell group. In the Ketchikan district, embracing the southern part of southeastern Alaska, there has been some exploitation of auriferous lodes. Though some of these have carried high values, they are all comparatively small, and many have proved not very persistent.

The value of the total gold output of southeastern Alaska from 1880, when mining first began, to the close of 1907, was nearly $40,000,000, which has come chiefly from the lodes. Its future as a gold producer is promising, yet, excepting the few developed mines, there is but a small tonnage of ore in sight. With the densely forested conditions that prevail, the search for ore bodies has been much impeded, and in spite of its accessibility the region can not be said to have been carefully prospected. There is therefore little on which to base predictions of future production, except the geologic conditions which are favorable to the discovery of new ore bodies. The deepest workings (1,600 feet in the Treadwell mine) indicate a persistence of gold content in deposits of this type which is encouraging.

ST. ELIAS RANGE.

Auriferous sands whose materials have been derived from the metamorphic rocks of the St. Elias Range have been found and mined in a small way at a number of localities. These and what is known of the rocks of this range suggest that here may be a locus of future gold mining, but the facts at hand do not permit a definite statement.

KENAI PENINSULA AND KODIAK ISLAND.

Auriferous gravels have long been known to occur on the Kenai Peninsula. In fact, it was here that the Russian mining engineer Doroshin found the first placer gold (1884) known in Alaska. The placers of the northern part of the Kenai Peninsula have been productive since 1895, with an aggregate output valued at about $2,000,000. For several years, however, the production has fallen off, and it appears that the richest of the known gravels have been exhausted, though there are extensive bodies of alluvium carrying low values. The gold has been derived from metamorphic rocks, and intrusives appear to be absent. The same geologic conditions appear to prevail throughout the eastern part of the peninsula, and other discoveries may be made. Both in the Kenai Peninsula and on Kodiak Island, which lie in the same general geologic province, some auriferous lodes have been found. The accessibility of this region would permit the mining of low-grade ores, so that there is a possibility of a gold production from this district even after the placers have become exhausted.

SUSITNA BASIN AND ALASKA RANGE.

Auriferous gravels are widely distributed in the Susitna basin and have been found on both flanks of the Alaska Range. It is only within a few years that workable placers have been found, and the entire production does not exceed a few hundred thousand dollars in value. The geologic conditions in the Alaska Range are in some respects very similar to those of southeastern Alaska and are therefore favorable for the occurrence of auriferous deposits. In view of the unexplored condition of much of this field, it is useless to attempt any forecast of its future from the mining standpoint.

COPPER RIVER BASIN.

There are two widely separated auriferous areas in the Copper River basin. The northern area lies on the south flank of the Alaska Range, and the southern area is a western extension of the St. Elias Mountains. What has been said of the future of mining in these ranges applies to these districts excepting that there has been some gold output from these, and they will undoubtedly continue to produce, as systematic mining has hardly commenced.

ALASKA PENINSULA AND ADJACENT ISLANDS.

The Alaska Peninsula region furnishes the only developed example of the third type of auriferous deposits, namely, an occurrence in volcanic rocks. This is at the Apollo mine, which has made a considerable production. Recent information leads to the opinion that there are other similar types of deposit in this general region. If such prove to be the case, this district may also swell the gold production, though at present its entire annual output is confined to a few thousand dollars taken from beach placers and a small production from lode deposits.

YUKON BASIN.

Mining was begun in the Alaska Yukon about 1887, when the Fortymile placers were discovered, but the total production up to the time of the discovery of the Fairbanks placers in 1901 was less than $6,000,000 in value, whereas the production for 1901 to 1907, inclusive, is valued at nearly $30,000,000.

The best known and probably most valuable of the placers of the Yukon basin lie in the so-called "Yukon-Tanana region," embracing an area of some 40,000 square miles between the two rivers, of which about half falls in what may be designated as the "auriferous zone." Within this province lie the Fortymile, Birch Creek, Fairbanks, Rampart, and Hot Springs districts, as well as some smaller ones, all of which have produced placer gold.

This province is the best example of gold occurring in metamorphic schists, but some of its auriferous deposits appear to be intimately associated with intrusive rocks. So far as known, the geologic conditions which prevail in the developed placer districts persist over much of this field. Certain it is that auriferous mineralization is widely distributed, for fine particles of gold occur nearly everywhere in the alluvium. Much of the Yukon-Tanana region is so inaccessible as not to attract the large operator. While the bonanza hunter has hurriedly traversed most of this region, the scarcity of bed-rock exposures and other conditions adverse to prospecting prevent such hasty investigations from yielding definite results as to the presence of gold deposits. Even in the best-known and most accessible parts of the region new discoveries of placers are constantly being made. All these facts indicate that this may be one of the largest placer-gold reserves of the Territory.

The data bearing on the gold contents of the gravels known to carry values have been carefully assembled by L. M. Prindle and F. J. Katz, and these indicate a reserve of about $100,000,000 in value for the ground which has been more or less prospected. This is certainly a conservative estimate, for it takes into account only the auriferous gravels which can probably be mined under the present conditions, or those that will prevail during the next few years, and does not make any allowance for the large unprospected areas.

A belt of schists lying north of the Yukon, extending from Chandalar Valley into the Koyukuk Valley, has been found to be auriferous. Mining has been going on in the latter district since 1899, with a production of probably over a million dollars in value. This field is one of very high cost in mining, and there are probably more extensive deposits with a smaller gold tenor than those now exploited. The Chandalar district has made but a small production, mining having been begun in 1906.

Placer gold has been found at several places in the lower Yukon basin, notably on the Melozikakat, on Ruby Creek, and on the Innoko. Too little is known of the character or extent of these deposits to permit any statement as to their future importance. They prove, however, a wide distribution of the auriferous deposits and indicate possibilities in the way of future discoveries.

Nowhere in the Yukon basin has there been any lode mining, and systematic prospecting for auriferous veins has hardly been inaugurated. As a rule, the mineralization in the schists appears to be disseminated rather than concentrated, but there are exceptions to this rule. Some lode deposits have been found which, in a more accessible region, could probably be profitably exploited. The subject of the future of lode mining in this field does not admit of solution from the data in hand.

SEWARD PENINSULA.

Placer mining was begun on Seward Peninsula in 1897, but it was not until 1899 that the annual gold production exceeded $100,000 in value. The total output of gold up to the close of 1907 was over $44,000,000 in value. Practically all of this gold was taken from the placers, for only one small lode mine has made any considerable production, though a few tons of ore have been taken from several others.

The auriferous deposits of the peninsula can be roughly outlined as occurring in two general belts. One, about 40 miles wide, stretches a little north of east and skirts the southern shore line of the peninsula, embracing the gold placers of Nome, Solomon, and Council. This belt has been traced about 120 miles. The second belt stretches from the neighborhood of Port Clarence to Kotzebue Sound, a distance of about 140 miles, with a width of about 40 miles. In this belt are included the auriferous gravels of Teller, Kougarok, Inmachuk, and Kiwalik. As outlined, these belts embrace an area of about 10,000 square miles. In addition to these areas, evidence of mineralization has been found in the extreme western part of the peninsula, which includes the cassiterite, galena, and other ores of the York region.

In describing the geographic distribution of the mineral deposits of the peninsula, it is not intended to imply that there is any great regularity in their occurrence. As a matter of fact, the distribution of the valuable minerals within these zones is very irregular. The placer gold seems to have been derived, for the most part, from contact zones between massive limestones and various types of schists. P. S. Smith's recent investigations show that other forms of auriferous deposits are those found in black siliceous slates and those in chloritic schists. Other types of mineral occurrence are those of cassiterite, galena, and other ores which are found in association with granitic intrusives near the western end of the peninsula and which have recently been described by Adolph Knopf.

While the types of mineral occurrence might be multiplied, for they include copper, antimony, tungsten, and other ores, what has been stated is sufficient to show that there is great variety in the form of mineralization. It also indicates that, in spite of the fact that there is now but little lode mining there is sufficient ground to believe that such an industry may be developed as to make it necessary to take it into account in estimating the gold reserves.

Though the Seward Peninsula auriferous gravels have been far more prospected than those of the Yukon-Tanana region, yet quantitative data of their gold contents are exceedingly scant. These data, however, were carefully compiled some years ago, and deductions made from them regarding the placer-gold reserves. Estimates were made by two different methods. By one the gold contents of auriferous gravels was valued at $265,000,000; by the other, $325,000,000. It can not be too often repeated that such computations are no more than mere approximations, for they are based on certain assumptions as to the gold tenor of the gravels, etc., which do not now admit of proof. These reserves appear to be two or three times as large as those estimated for the Yukon-Tanana region. This is due to the fact that in Seward Peninsula the data seemed to justify an attempt at an estimate of gold tenor for the entire body of auriferous gravels, while in the Yukon-Tanana region the information at hand only warranted an estimate of the auriferous gravels of the productive areas.

STATISTICS.

The systematic collection of statistics of gold production for Alaska was begun only in 1905, and the distribution of the output previous to that year is only an approximation. In the preparation of the following table the best available data have been used. In this table of production the Pacific coastal belt includes southeastern Alaska, the St. Elias region, and the Alaska Peninsula and adjacent islands, while under Copper River and Cook Inlet region are embraced the Kenai Peninsula and the Copper River and Susitna basins. The other geographical terms used in this table, Yukon basin and Seward Peninsula, need no definition.

Value of gold production of Alaska, with approximate distribution, 1880–1907.

Year.	Pacific coastal belt.	Copper River and Cook Inlet region.	Yukon basin.	Seward Peninsula.	Total.
1880	$20,000				$20,000
1881	40,000				40,000
1882	150,000				150,000
1883	300,000		$1,000		301,000
1884	200,000		1,000		201,000
1885	275,000		25,000		300,000
1886	416,000		30,000		446,000
1887	645,000		30,000		675,000
1888	815,000		35,000		850,000
1889	860,000		40,000		900,000
1890	712,000		50,000		762,000
1891	800,000		100,000		900,000
1892	970,000		110,000		1,080,000
1893	833,000		200,000		1,038,000
1894	882,000		400,000		1,282,000
1895	1,569,500	$50,000	709,000		2,328,500
1896	1,941,000	120,000	800,000		2,861,000
1897	1,799,500	175,000	450,000	$15,000	2,439,500
1898	1,892,000	150,000	400,000	75,000	2,517,000
1899	2,152,000	150,000	500,000	2,800,000	5,602,000
1900	2,606,000	160,000	650,000	4,750,000	8,166,000
1901	2,072,000	180,000	550,000	4,130,700	6,932,700
1902	2,546,600	375,000	800,000	4,561,800	8,283,400
1903	2,843,000	375,000	1,000,000	4,465,600	8,683,600
1904	3,195,800	500,000	1,300,000	4,164,600	9,160,000
1905	3,430,000	500,000	6,900,000	4,800,000	15,630,000
1906	3,454,794	332,000	10,750,000	7,500,000	22,036,794
1907	2,891,743	275,000	9,183,000	7,000,000	19,349,743
Total	40,311,937	3,342,000	34,964,000	44,262,700	122,935,237

Of this about $37,000,000 must be credited to the lode production, which is nearly all included in the Pacific coastal belt of the above table. Up to the close of 1907 there was only one productive auriferous lode mine in Seward Peninsula, and none either in the Yukon basin or in the Copper River and Cook Inlet region. The auriferous lode production, with the exception of that of the Apollo mine on Unga Island, southwestern Alaska, and a few small mines of the same general region, together with a small gold output from the copper deposits of Prince William Sound and from the auriferous lodes of Seward Peninsula, is all from southeastern Alaska. As the Treadwell group of mines has an output valued at $30,402,236, it will be seen that nearly five-sixths of the auriferous lode production is from this one ore body.

Accurate data regarding the source of the gold have been available only since 1906. They are summarized in the following table:

Source of gold in Alaska, 1906–1907, in values.

Kind of ore.	1906.	1907.
Placers	$18,607,000	$16,491,000
Siliceous ores	3,348,943	2,764,885
Copper ores	80,851	93,858

This table indicates that the placer production now overwhelmingly dominates in the total of gold output. This has, however, only been true since 1897, for previous to that time only about a third of the annual gold production was from the placers.

SUMMARY AND CONCLUSION.

It has been shown that gold is very widely distributed in Alaska, both in lodes and in placers; also that the production of the lode mines, outside of the Treadwell group, is insignificant. This does not mean, however, that the outlook for auriferous lode mining is not hopeful, for this is far from being the case. Up to the present time the cost of mining, except along a part of the Pacific seaboard, has been practically prohibitive for a lode-mining industry which is not based purely on the exploitation of bonanzas. Even along the seaboard there has been little systematic search for lodes. Most of the gold ores which have been found in the inland region have been of so low a grade as not to encourage their exploitation under present conditions of transportation. It will be clear, therefore, that there is no basis whatever for a quantitative statement of the gold reserves in the lodes of the Territory.

The known wide distribution of placer gold augurs well for future discoveries of this type of deposit. Most of the districts where mining operations are now going on have been so little prospected that little is known of their gold reserves. Some estimates, however, have been made for placer-gold reserves of the Yukon-Tanana region and Seward Peninsula. Those of the first province were made to include only the producing areas, while in Seward Pensinsula the bulk and value of the entire body of auriferous gravels was estimated. In the Yukon-Tanana region, which includes much the largest auriferous area, the gold contents of the producing part of the field are approximately valued at $100,000,000, not including the very large unprospected areas, while the auriferous gravels of the entire Seward Peninsula are estimated to contain about $300,000,000. It can not be too strongly emphasized that though all the data have been carefully compiled and the computations made with great care, yet there are so many unknown factors that the results are little more than guesses. No quantitative data of any kind are available for the other smaller districts, ten in number, but it is probably safe to estimate the gold in them as between $50,000,000 and $100,000,000. These values total about $500,000,000, which is the nearest approximation that can be given of the gold-placer reserves of the Territory. It is not impossible, however, that the Yukon-Tanana region alone may carry this amount of gold.

SILVER, LEAD, AND ZINC.

The silver production of Alaska has practically all been won incidentally to gold mining, and much the larger part of it has been recovered from the placer gold. There has also been a small recovery from the copper ores.

The total production of silver from 1880 to 1907, as nearly as can be determined, was 1,677,159 ounces, of which over three-quarters was from the placer gold. The following table shows the source of silver for the period that statistics have been available:

Source of silver from Alaska, 1906–7.

Kind of ore.	1906.	1907.
	Ounces.	*Ounces.*
Placers	76,835	49,847
Siliceous ores	15,772	14,653
Copper ores	18,577	34,357

There has been no lead production from Alaska, except a few tons recovered in the reduction of other ores. Galena is widely distributed, and some promising ore bodies have been prospected, but nothing is known of their extent. Such galena deposits occur in southeastern Alaska, on Prince William Sound, and in Seward Peninsula. Though attempts to exploit a galena ore body on Seward Peninsula date back to 1881 and have been continued intermittently to the present time and some small shipments have been made, this mine, called the Omalik, has never been on a commercial basis. The same statement applies to the mining of galena ores in other parts of the Territory.

Zinc blende has been found at a number of localities in Alaska, but the value of the ore bodies remains to be proved. No attempt has been made to mine zinc ores.

There are no data at hand on which to base any estimates of the reserves of the three metals here under consideration. With the increase of the gold output there will be a corresponding increase in the silver production.

COPPER.

DISTRIBUTION AND OCCURRENCE.

Copper ores are known to occur in commercial quantities on Prince of Wales Island (southeastern Alaska), Prince William Sound, and in the Chitina Valley of the Copper River district. They have also been found in a belt running from the Nabesna to the upper White River, in the Lake Iliamna region, and on the Seward and Kenai peninsulas. In these no ore bodies of proved commercial importance have been opened up, but the outlook for such in some localities appears hopeful.

On Prince of Wales Island, according to C. W. Wright, the copper ores, which are sulphides, occur along the contact of intrusives and limestones. U. S. Grant's description of the copper ores of Prince William Sound shows these to be sulphide ores which occur as lenses along shear zones. These shear zones are in greenstones or in contact zones between greenstones and graywackes. The Chitina belt, according to F. H. Moffit, includes both native and sulphide copper deposits. These occur at or close to a contact between a heavy greenstone (altered lava) and a limestone. This contact, along which mineralization seems fairly persistent though ore bodies of proved value have been exposed at only a few localities, has been traced for upward of a hundred miles.

The Nabesna-White River copper belt is of a similar character to that of the Chitina Valley, though here the value of the ore bodies found remains to be proved by further development work. In the Iliamna Lake region copper ores are said to be similar in occurrence to those of southeastern Alaska. Little is known of the other copper-bearing localities of the Territory.

STATISTICS.

Copper mining was first attempted on Prince of Wales Island in 1880, but the project was soon abandoned. The industry was begun again in 1900 in Prince William Sound, and five years later the Prince of Wales Island deposits also began producing. The total output of copper from Alaska up to the close of 1907 was 20,843,352 pounds, of which 12,368,975 pounds came from the Prince of Wales Island mines and the balance from Prince William Sound.

SUMMARY.

It is impossible to make any estimate of the tonnage of copper-ore reserves of the Territory. The developed ore bodies have been computed in a few mines by the operators, but even if these figures were available they would have little bearing on the problem of the ultimate reserves. Less than a score of copper mines have been opened up in Alaska, and all but one of these are located in two districts. In one promising district there has been only a little surface prospecting and this also holds true of the several widely distributed copper deposits which are not included in the four best-known districts. Even in the largest mines the workings in few cases extend to a depth of more than one or two hundred feet. It is evident, therefore, that the ore blocked out in the mines, whose copper content is probably less than 200,000,000 pounds of metal, has little bearing on the question of ultimate reserves, for it would not take into account either the undeveloped ore bodies already found or the possibilities of discoveries in the little-prospected fields. Moreover, any estimate of tonnage could include only the ores which can be mined at the present price of copper, while an increase of this price would make available lower-grade ores which can not now be commercially exploited. The problem is furthermore complicated by the irregularity of many of the copper deposits.

There can be no doubt that the output of copper from the Territory will increase during the next few years. The accessibility and cheapness of exploitation of the ores of the Pacific coast province invite copper-mining enterprises, in spite of the irregularity of occurrence of most of these deposits. A railway is now under construction up the Copper River valley which will not only lead to early shipments of a large amount of copper ores from the deposits already found, but will also stimulate further search and probably lead to the discovery of other ore bodies.

WATER RESOURCES.

INTRODUCTION.

The principal value of the water resources of Alaska is for generating power to be used for mining, now the only extensive industry. There are two general methods of utilizing the water power: (1) By converting it into electricity or other form of energy, for the purposes of lode and placer mining. By such means the power can be transmitted to the locality of use. This form of utilization is now almost entirely confined to the Pacific coastal belt of the Territory. (2) The more direct use of the water under head for sluicing, elevating, and hydraulicking the auriferous alluvium. This second form of utilization has been extensively practiced in small plants throughout the placer districts.

Many of the gold placers and lode deposits can be profitably exploited only by the utilization of water power. The water powers are also valuable to other industries, but up to the present time have not been so utilized, except in a small way for running electric-light plants, machine shops in some of the coastal towns, and some fish-product manufactories.

An adequate knowledge of the distribution, volume, and gradients of the surface water is, therefore, of first importance to the industry of the Territory. The underground waters of Alaska need not here be considered; none such have been developed and little is known about their occurrence. There is a possibility that in some of the placer districts there may be underground waters in sufficient quantity to justify their development for purposes of supplementing the inadequate surface waters. Artesian waters have in a few instances been found underneath the layer of perpetually frozen ground. These appear to be exceptional conditions, as usually the frost extends all the way to bed rock. Such ground waters, where they have been found, are probably very local in extent. There are also some potable waters derived from springs, but these, as well as the surface water used for towns, need not here be considered.

Facts regarding the water supply are scant and based almost entirely on the results of the investigations of the United States Geological Survey. These results are of two kinds—(1) the records of stream gaging, which furnish information as to the volumes of the watercourses, and (2) the topographic maps, which show the distribution of the water, as well as the gradients of the streams in which it flows. Measurements of stream flow have been carried on for three seasons (1906–1908) in some of the important placer districts of Seward Peninsula, for two seasons (1907–1908) in the Fairbanks district, and for one season (1908) in the Hot Springs, Rampart, and Birch Creek districts. These measurements furnish the only data on stream volume throughout the Territory, though a few corporations have obtained records from small areas preparatory to the installation of hydraulic plants.

The topographic data are more complete, for reconnaissance maps (scale 1:250,000, with 200-foot contours) of some 121,252 square miles have been made which cover most of the important mining districts and about 20 per cent of the entire area of Alaska. These reconnaissance maps furnish a general conception of drainage basins and stream gradients. In addition, 2,732 square miles have been mapped in detail (scale 1:62,500, with 25, 50, or 100 foot contours), yielding accurate information of the extent of drainage basins and of stream gradients.

Only two of the larger geographic provinces of Alaska will here be considered, namely, (1) the Pacific coastal region and (2) the central region, for, as far as can now be foreseen, it is only in these two that the water has any industrial value. These two provinces differ essentially in climate and relief and, indeed, present almost the extreme conditions as regards the occurrence and utilization of surface waters. In the coastal belt as a whole the topography is extremely rugged and many of the streams are fed by perennial snows, which, together with the large precipitation (75 to 120 inches), yield a large run-off with no great fluctuations during the summer months.

Beyond the coastal barrier the climate is semiarid (precipitation 10 to 20 inches), the relief is weak, and hence stream gradients are low, while there is no permanent snow. Another feature of the precipitation is that summer rainfall is very local. Moreover, the general frozen condition of the subsoil to bed rock probably prevents any considerable ground storage. These conditions make for a small run-off per square mile and very marked fluctuations in stream volumes. Moreover, the low relief makes it difficult to utilize the water under head.

Seward Peninsula, though not strictly a part of the central region, possesses the same general hydrographic conditions. The precipitation (10 to 30 inches), however, averages a little greater than in the Yukon basin. Here also the low stream gradients make much of the run-off unavailable for placer mining.

The conditions affecting surface waters in the area drained by Susitna and Copper rivers differ somewhat from those existing in the Pacific coastal region and in the inland province. In part this area has as strong relief as that along the seaboard, yet its precipitation is far less. On the whole, however, this region is better supplied with water than the Yukon basin.

PACIFIC COAST REGION.

In southeastern Alaska alone has there been any considerable utilization of water power. The Census Bureau collected the statistics of the developed water power in this part of the territory. Through the courtesy of the Director of the Census the following data are available. The statistics show that a total maximum of 15,699 horsepower has been developed and that 100 water wheels have been installed. Of this maximum 2,816 horsepower is available during low-water season. It is reported that at the localities where this power has been developed there is 14,135 horsepower available. Of the developed horsepower 3,403 horsepower is utilized by electric-light plants, canneries, and some other small industrial enterprises, and the rest by mining and smelting plants. The Treadwell group of mines alone utilizes some 6,647 horsepower. In addition to the above a few hunded horsepower is developed in other parts of the Pacific coast belt.

Southeastern Alaska affords conditions which are peculiarly favorable for the development of water power. The glaciation of this region has developed a topography which, with its cirques and many lakes lying at considerable altitude above sea level, is favorable to water storage. While the run-off during the summer months is much larger than during the winter, yet there are many localities where a large amount of power can be developed, even during the low-water stages.

YUKON BASIN.

There are no records which make it possible to state the quantity of water used for placer mining in the various Yukon districts, but it is known to be a large amount. Nor has stream gaging progressed far enough to determine the available water. However, it is probably safe to say that within a few years every supply so situated as to be directly applicable to placer mining will be utilized. Even when this has been brought about, the supply will be inadequate for the gold placers already opened up. In addition to this water directly applicable to placer mining, there are a number of water powers which can be utilized for certain mining operations by transformation to other forms of energy. It is probable that even after the development of these water powers the demands of future mining interests will not have been met. The utilization of coal to supply this demand is discussed elsewhere in this report. Mention should be made in this connection of the possibility of developing power along the streams which find their source in the high mountains stretching along the southern margin of the Yukon basin. These streams have not been measured and but few have been surveyed. They are known, however, to have a much larger volume than those of the central region proper, and the topography would appear to be favorable to water-power development. Some of the important placer districts lie within 50 or 100 miles of the mountain front.

The following table, which is based on the investigation of Mr. Covert, presents in summary form the available data regarding the run-off in the districts which have been investigated. It can not be too strongly emphasized that, as this is based on only one or two seasons' observations, the data presented are only an approximation.

Estimates of mean annual discharge and run-off of drainage basins in Yukon-Tanana region, Alaska.

[By C. C. Covert.]

District.	Year.	Second-foot per square mile.	Depth in inches.	Per cent estimated.[a]	Duration of record. From—	Duration of record. To—
Fairbanks, 826 square miles	1907	0.780	10.60	62	June 20	Oct. 15
	1908	.710	9.66	54	May 1	Oct. 21
Mean		.745	10.13	58		
Hot Springs, 56 square miles	1908	.44	6.00	95	June 6	Sept. 26
Rampart, 212 square miles	1908	.54	7.40	90	...do....	Do.
Circle, 2,150 square miles	1908	.99	13.50	91	June 26	Oct. 13

[a] The run-off for the period not covered by records was estimated at approximately 0.25 second-foot per square mile.

SEWARD PENINSULA.

What has been said of the Yukon basin applies also to Seward Peninsula. Here, too, nearly all the water available for direct application to placer mining will soon be utilized, and even then can not meet the demand. Some important undeveloped water powers are known to exist in this province.

The topography of Seward Peninsula, like that of the Yukon basin, is of low relief, and therefore a comparatively small part of the run-off can be made available for mining. In the mountain mass, including the Bendeleben and Kigluaik ranges, the conditions for water storage are somewhat more favorable than in other parts of the peninsula. Here there are some glacial cirques, and though these are of comparatively small extent, they have an influence in the conservation of water and snow. What is of still greater importance, however, is the greater rainfall which occurs in these high mountains compared with other parts of the peninsula.

Mr. Henshaw has summarized his three seasons' observations on stream flow in Seward Peninsula in the table which follows. The value of the data contained in this table will be increased by considering the character of the topography of the basins whose run-off is given. Kruzgamepa River, at Salmon Lake, drains a basin typical of the Kigluaik and Bendeleben mountain areas. Kuzitrin River and Imuruk Lake lie in the northern portion of the peninsula and represent the area north of the mountains. There are not sufficient data to make any estimate of the yearly run-off from the country south of the mountains.

Estimates of mean annual discharge and run-off of drainage basins in Seward Peninsula, Alaska.

[By F. F. Henshaw.]

Stream.	Year.	Second-feet per square mile.	Depth in inches.	Per cent estimated.	Duration of record.	
					From—	To—
Kruzgamepa at Salmon Lake, 81 square miles	1906	3.68	50.2	38	May 28, 1906	Sept. 30, 1906
	1907	3.77	51.1	40	June 15, 1907	Oct. 5, 1907
	1908	2.40	32.6	63	June 21, 1908	Sept. 30, 1908
Mean		3.28	44.6	47		
Kuzitrin at Lanes Landing, 1,720 square miles	1907	.46	6.2	100		
	1908	.39	5.3	40	June 1, 1908	Sept. 30, 1908
Mean		.42	5.7			
Imuruk Lake, 99 square miles	1906–1907	.59	7.9		Aug. 16, 1906	Aug. —, 1907
	1907–1908	.50	6.8		Oct. —, 1907	Sept. 25, 1908
Mean		.54	7.4			

The discharge of Kruzgamepa River at Salmon Lake has been assumed to decrease regularly from October 1 to a minimum of 30 second-feet on April 20, then to increase slowly until the break-up of the ice, and more rapidly until the date of the beginning of records, which has been taken as the maximum for the year. The run-off from snow for 1908 was taken as 70 per cent of the mean of that for the two previous years.

The run-off of Kuzitrin River for May, 1908, was taken as 75 per cent of that for June, and for the remainder of the year as 0.06 second-feet per square mile. The run-off for 1907 was estimated by comparison with the two years' record at Imuruk Lake. The flow into Imuruk Lake was determined by closing the dam at the outlet and noting the rise of the water surface.

WASTE OF STRUCTURAL MATERIALS FROM FIRE AND OTHER CAUSES.

By Herbert M. Wilson,
United States Geological Survey.

The mineral structural materials may be divided into two classes:

(*a*) Iron, steel, copper, and other metallurgical products, the supplies of which are limited and which are themselves subject to destruction through weathering, fire, etc., and

(*b*) Stone, clay products, and cement and concrete manufactures, which are less subject to destructive agencies and the supplies of which are practically inexhaustible.

The substitution of the latter materials for the more commonly used wood and metal manufactures should be encouraged as having an important influence on the preservation of the supplies of the more perishable and less abundant materials. The use of building stone, clay, and cement products in this country has been restricted by competition with the much cheaper wood products and the more easily fabricated and more available metal products. Improved methods of preparing the raw materials for use in building construction are rapidly reducing this difference in cost, and careful investigation both as to the physical properties and the more suitable structural forms should have an important influence on further reducing this difference in cost and the enlargement of the use of the more permanent and less perishable materials.

The value of the cement manufactures has increased from $9,859,-000 to $55,803,000 within the last decade, or nearly sixfold. The value of the clay products has increased in the same time from $74,-487,000 to $185,942,000, or over double, while the building stone has in the same period increased in value from $28,635,000 to $71,106,000, or nearly three times. As the Government, through its investigations, is determining the strength, durability, and fire-resisting properties and the more suitable forms of these materials and disseminating information relative to the comparative cheapness and greater permanence of such materials, a still greater relative increase in their use may be confidently looked for in the near future.

Within the past few years marvelous strides have been made in the substitution of iron and steel for wood, owing to the careful investigations into their properties made by engineers, physicists, and chemists and the great amount of attention given their fabrication by manufacturers and architects. More recently the engineering and technical professions have advanced to a great extent the uses of cement and concrete manufactures; but in a vastly greater period of time practically nothing has been done toward ascertaining the physical and chemical properties and better mode of manufacture and use of the products of clay and stone. Undoubtedly great progress in the substitution of all of these materials for metal and wood in building construction may now reasonably be looked for, with proper encouragement from the Government as an exemplar in the methods of testing and assembling such materials.

WASTE OF STRUCTURAL MATERIALS.

The waste of natural mineral resources used in building and engineering construction is of three kinds:

(1) That due to improper and wasteful methods of mining and preparing for market.

(2) That due to excessive use in structural forms, because of ignorance of the strength, durability, etc., of the materials used.

(3) That due to destruction by fire on account of the inflammable character of building construction, inadequate building laws, and the nonenforcement thereof.

The waste of raw mineral products due to improper methods of mining and shipping is fully discussed elsewhere in this report. There is an equally large waste of these materials due to uneconomical and inefficient methods of manufacture, including waste of the fuel, as in the preparation of coke used in refinement of iron ores and of fuel used in burning cement, clay products, etc. Not until a better knowledge is had as to the appropriate structural material, be it steel, iron, stone, cement manufactures, or clay products for any particular purpose, will it be possible to reduce a portion of this wasteful consumption.

Most of the information available concerning the strength and suitability of such materials has been procured by individuals, based on insufficient data and tests. The Government, as the largest consumer of such materials, should, as a matter of economy, conduct exhaustive tests of the kinds which have proven so successful under the Forest Service in developing the most suitable woods for each particular use. These tests should be conducted with a view to establishing the physical properties of these materials and to suggesting improved methods of manufacture which may prove not only economical, but shall improve the quality of the materials in use and extend their life. These investigations should include the assembling of information relative to the most fire-resisting and fireproof forms of construction, the former having in view the prevention of conflagrations due to secondary or exposure fires, and the latter the prevention of the destruction of the building in which the fire may originate. They should also include extended investigations with a view to preventing the loss of structural materials exposed to the action of salt water, the action of alkalies in the arid regions, and to similar destructive agencies.

A great many structural materials are used in excessive quantities in the erection of buildings and engineering works, while materials of superior quality may be little used because of lack of information as to their properties. The average architect, engineer, or contractor does not take chances of using unfamiliar materials or designs, but confines himself to those he has knowledge of as having proven moderately successful. Authoritative investigations should be made of such materials with a view to establishing the strength and properties of each under varying conditions, and of pointing out the most economical material for each use. The present systems of building construction are expensive and wasteful, because of lack of exact knowledge as to the strength of the materials when fabricated into various forms of construction.

The investigations so far conducted by the Geological Survey indicate the local availability of gravel, sand, or broken stone suitable for making concrete or reenforced concrete structures, where it had been previously assumed that such materials were not suitable and the charge for haulage from distant quarries often rendered the cost of such construction excessive. A better knowledge of the distribution of these constituent materials of concrete, and of the building stones and clays locally available, will encourage the use of these durable structural materials in competition with forest products and other less permanent materials, thus conserving the latter.

The use of excessive quantities of structural materials, due to ignorance as to their strength, results from the very incomplete tests regarding such strength, in the absence of which conservative designers use an unnecessarily large factor of safety. Engineers and architects adopt working stresses for metal and reenforced concrete of from one-fourth to as high as one-eighth the supposed working strength of the material, which may mean that from three to six times the amount of material that is necessary is being used. But lighter designs can not safely be adopted until absolute knowledge is had, through long series of tests and investigations, which will thoroughly establish the strength and durability of each structural material for the specific purpose for which it is to be used.

As shown elsewhere in this report, the iron resources of the world, and those of the United States in particular, are not limitless. According to the present ratio of increase in consumption of iron and steel products, the supply of these materials in the United States will be exhausted in a few centuries. The forest products of the United States are rapidly approaching exhaustion, and unless immediate means be taken to limit their waste and reproduce their growth, a fraction of a century will see their exhaustion. Under the circumstances, we must turn to concrete-making materials, such as cement, sand, and gravel, to the raw clay from which brick and tile are manufactured, and to building stones, the amounts of all of which in the United States are practically unlimited, as substitutes for the above more perishable materials.

FIRE LOSSES.

The greatest source of waste of structural materials and of money values in the United States is that due to fires and this is one which from the example set in European countries can, as hereafter shown, be most greatly reduced by the substitution of fire-resisting building materials for the inflammable construction now so prevalent.

The cost of fire to the country, including not only property destroyed, but maintenance of fire departments, payment of insurance premiums (less benefits returned), protective agencies, additional cost of city water supplies to meet fire drafts, etc., amounted to over $456,-

485,900 in 1907. This fire tax exceeded the total value of the gold, silver, copper, and petroleum production of the United States in 1907 and was thirteen times the interest on the national debt. The property loss from fires in the United States in 1907 was $2.51 per capita. The total per capita loss, including interest and maintenance charges on fire departments, excessive water supplies, insurance premiums, etc., was $5.34.

In addition, 1,449 persons lost their lives in fires during the year 1907, while 5,654 were injured. The loss of life during 1908 was even greater, on account of the Boyertown (Pa.) opera-house fire and the Collingwood (Ohio) school disaster. Undoubtedly the greater part of this immense waste in material, money values, and lives could be prevented by the use of suitable structural materials and the better fabrication of these into building construction. Such construction would cost little more than the present combustible building, and would result in real economy in the long run, and in the extension of the life of the mineral and forest resources.

Possible means of reducing this enormous waste due to fire and conflagration are:

(1) By tests and investigations to determine the relative fire-resistive properties of building materials, the relative rates of heat conductivity of such materials, and the developments of systems of construction which offer the maximum resistance to fire. These tests should have in view the classification in order of merit of the building materials and the cheapening of cost of construction by the use of those best suited to the purpose, since materials actually cheaper are often not employed through lack of knowledge of their available properties.

(2) By the dissemination of information regarding the less inflammable materials of construction, their strength and durability, the methods of utilizing them in building construction, and the availability of the most suitable of these materials near the locality in which they are wanted.

(3) By the enactment of building codes and the enforcement of the same with a view to securing more fire-resistant and more fireproof construction. In European cities the erection of wooden buildings is prohibited, and the official supervision of brick, stone, steel, and cement construction is such as to diminish danger from fire due to defective flues, poor electric wiring, etc., and as to confine the fire to the building in which it originates.

The fire waste in the United States for the year 1907 reached the enormous total of $456,485,900, exclusive of forest, mine, and marine fires. Of this total $109,156,894 was due to the destruction of buildings and $105,927,815 to the loss or injury of contents. A noteworthy fact is that of this loss 27 per cent was due to exposure, i. e., the fire extended beyond the building of origin. This loss is quite evenly distributed between urban and rural districts; the loss in cities amounting to $107,093,283, and in villages and the country $107,991,426, and as the urban and rural population are almost exactly equal the per capita loss in each division is very evenly divided. Only $68,000,000 of this loss was on brick, iron, stone, and other slow-burning constructions, while over double this amount, or $146,000,000, was on frame buildings. In the last thirty-three years the total fire waste, being the value of property destroyed, amounted to over $4,484,000,000, while the total cost of such fires doubtless aggregated double this vast sum.

Even where frame buildings are permitted or are now in existence, the loss might be greatly reduced by more careful oversight over defective flues, wiring, etc.

The cost of insurance amounted to $145,604,344, being the difference between the total premiums paid on policies, $259,768,813, and the benefits paid to the insured, $114,164,469. The cost of fire-department maintenance and interest on capitalization amounted to $44,237,100 of the total. The interest on the capital cost of fire-protective devices, such as automatic sprinklers, fire extinguishers, etc., and the annual cost of private watchmen's service, etc., amounted to about $18,000,000. The total for the year 1907 is swelled by the amount invested in city water-supply service and distributing systems primarily necessary for fire protection and over and above that estimated as necessary for domestic consumption. This includes interest on the capital invested in city fire protection, $9,826,800, and maintenance charges, $8,465,500, the sum of which aggregates about 22 per cent of the total cost of water supply. The depreciation charges and taxes on all the above amounted to $15,167,500.

A large portion, probably over one-half of the insurance, one-fourth of the city water-supply and distribution charges, one-half of the fire-department charges and three-fourths of the fire losses, or a total of $234,196,956 per annum, may be reasonably expected to be saved, when through the dissemination of information relative to less inflammable structural materials and the enactment of better building codes, building construction in the United States shall become of a kind similar or superior to that now found in European countries.

HOW THE STATISTICS WERE GATHERED.

The details making up the above summary of fire losses of structural materials and property values, as well as the invested capital, are submitted in the following tables and discussion, chiefly the work of John L. Cochrane, statistician, assisted by Frank D. Brown:

At the request of the National Conservation Commission, the United States Geological Survey, through its technologic branch, took up the task of gathering the statistics of fire losses of the country. Requests for the official records of fire loss were sent to the chiefs of fire departments in 5,175 incorporated places in the United States (all places of 1,000 population and upward) with the result that 1,000 replies were received. Four thousand second requests were sent out, and to these 1,796 fire chiefs responded, making a total of 2,796 cities and villages heard from out of 5,175.

These cities and villages, with a population aggregating 34,102,453 reported a fire loss of $86,476,029, or a per capita loss of $2.54.

It was with the greatest difficulty that figures were obtained showing separately the losses on frame and brick buildings, on buildings and contents, and losses on buildings in which fire did not originate, since many of the fire chiefs merely sent an estimate of the total loss. After much correspondence, 2,300 out of the 2,796 chiefs who replied originally gave the detailed figures.

In order to obtain a correct estimate of the losses in the rural districts, 5,000 blanks were sent to postmasters located in counties that were strictly rural, the aim being to exclude all counties that contained villages of any sizes whatever. The blanks were apportioned among the various States according to their percentage of rural population, the States with a large farming population getting more than the States whose population centered mainly in the cities. Responses were received from 1,898 postmasters representing a population of 1,410,383. These postmasters reported a total loss of $3,519,769, which gives a per capita loss of $2.49.

Thus it will be seen that reports were received from 4,694 cities, villages, and rural communities with a total population of 35,512,836 and a total loss of $89,995,798, a per capita loss for the entire United States of $2.51, or an aggregate loss for the United States of $215,084,709.

The only statistics with which these are comparable have been gathered by the National Board of Fire Underwriters. This organization, composed of the leading fire underwriters of the country, has given out estimates of the fire losses for several years, in the hope of showing the public how much of the loss is preventable and with a view toward creating a public sentiment in favor of better building construction.

In order to ascertain the additional cost imposed upon the country by fires over and above that represented by simple fire waste or destruction of property and the cost of public fire-fighting departments and systems and insurance losses above referred to, careful statistical inquiry was made into the additional cost of construction and maintenance of city water supplies necessary on behalf of protection against conflagration over and above cost pertaining to domestic supply, street sprinkling, and the incidental fire service necessary to restricting a fire within the building of origin. Information was also procured regarding the cost of private fire-protective measures such as automatic fire sprinklers, fire extinguishers, and grenades, private watchmen's services, etc., imposed by the risks due to inflammable construction. Finally, an attempt was made to ascertain the losses to the country from marine fires and disasters. The statistics regarding public water supplies were secured by correspondence and the submission of questions to the superintendents of water supply in every city in the United States and to the more prominent hydraulic engineers. In all, 5,700 blank report forms were sent out to which 1,500 replies were received, of which, however, but a small percentage was complete enough for tabulation. The total cost in each case was obtained from the census reports for cities of above 30,000 population owning waterworks and the remainder from the Spectator.

This total cost of waterworks systems in the United States was segregated to show the total cost in each of the five geographical divisions of the United States, viz: The Middle Atlantic and New England States; the Southern and Southeastern States; the Central States; the Rocky Mountain or arid region; and the Pacific Slope States.

The total cost of the waterworks systems in each of the geographical divisions was then subdivided to show the total cost in cities according to the following classification: Population of 100,000 or over; population of 30,000 to 100,000; population of 5,000 to 30,000; and population under 5,000.

This same plan of classification was pursued in tabulating the reports received from engineers and superintendents who gave in detail the information sought. This detailed information for each geographical division and classification by size of cities was then applied to the total cost of waterworks systems for the corresponding geographical divisions and classifications by size of cities, and the same proportionate distribution made for the various inquiries.

The procurement of data of losses from marine disasters was even more difficult than the above. This was arrived at by securing the total paid by American companies and the total paid by foreign companies doing United States business, giving an aggregate total for the year 1907 of $11,621,827. It is not evident that a portion of this may not include some Canadian insurance or cover some duplication. Endeavors to secure data on cost of private fire protection were even less successful. Information received from the manufacturers of automatic sprinklers, fire extinguishers, etc., and estimates of the cost of private watch service derived from special investigations in a number of prominent cases lead to the belief that the invested capital, including construction, equipment, etc., aggregates about $50,000,000, while interest upon this amount and the cost of watchmen's services, etc., would amount to an annual charge of about $18,000,000.

FIRE WASTE.

The total loss from fire in the United States during 1907, $215,084,709, represents a waste of nearly $600,000 for every day of the year, or $25,000 for every hour of the day. The term "waste" is used because the fire loss is one that is absolutely irretrievable, and constitutes a tremendous drain upon the natural resources of the country. The insurance on a burned building does not bring back the property that was destroyed—it simply equalizes the loss between all others whose property is insured—and the money paid by the insurance companies does not by any means cover the total losses sustained. Underwriters declare that from 75 to 80 per cent of all property is insured, but two State fire marshals disagree with this statement after tabulating the fire losses for their States. The State fire marshal of Ohio, D. S. Creamer, finds that but 52 per cent of the property is covered by insurance. This statement seems to be borne out by the annual report of the National Board of Fire Underwriters for 1907, which gives as the total losses paid by all companies during the year $114,164,469.

The fire waste for the last thirty-three years, according to the National Board of Fire Underwriters, reached the tremendous total of $4,484,326,831.

Fearful as it is to contemplate this great destruction of the natural resources of this country, the situation becomes more appalling when it is realized that this waste is rapidly increasing. The National Board of Fire Underwriters gives the following estimates of the fire waste for the last thirty-three years:

Annual fire losses in the United States for thirty-three years, 1875–1907.

[Compiled by the National Board of Fire Underwriters.]

Years.	Aggregate property loss.	Years.	Aggregate property loss.	Years.	Aggregate property loss.
1875	$78,102,285	1886	$104,924,750	1897	$116,354,575
1876	64,630,600	1887	120,283,055	1898	130,593,905
1877	68,265,800	1888	110,885,665	1899	153,597,830
1878	64,315,900	1889	123,046,833	1900	160,929,805
1879	77,703,700	1890	108,993,792	1901	165,817,810
1880	74,643,400	1891	143,764,967	1902	161,078,040
1881	81,280,900	1892	151,516,098	1903	145,302,155
1882	84,505,024	1893	167,544,370	1904	[a] 229,198,050
1883	100,149,228	1894	140,006,484	1905	165,221,650
1884	110,008,611	1895	142,110,233	1906	[b] 518,611,800
1885	102,818,796	1896	118,737,420	1907	199,383,300

[a] Baltimore conflagration.
[b] San Francisco earthquake and conflagration.

ANALYSIS OF LOSSES IN THE UNITED STATES.

The following table of the fire losses in the United States in 1907 gives a number of interesting comparisons of the total losses sustained in the cities and in the rural districts:

Fire losses in the United States for 1907.

[Statistics gathered by the United States Geological Survey.]

	Total.	Urban.	Rural.
Fire loss:			
Buildings	$109,156,894	$50,173,625	$58,983,269
Contents	105,927,815	56,919,658	49,008,157
Total	215,084,709	107,093,283	107,991,426
Brick, etc.:			
Buildings	31,092,687	19,816,474	11,276,213
Contents	37,332,580	29,092,270	8,240,310
Total brick, etc	68,425,267	48,908,744	19,516,523
Frame:			
Buildings	78,064,207	30,357,151	47,707,056
Contents	68,595,235	27,827,388	40,767,847
Total frame fire loss	146,659,442	58,184,539	88,474,903
Number of fires:			
In brick, etc., buildings	36,140	25,297	10,843
In frame buildings	129,117	80,109	49,008
Total number of fires	165,257	105,406	59,851
Loss per capita, United States	2.51	2.54	2.49

It will be seen that the loss is rather evenly divided between the urban and the rural population, the total loss in the cities and villages amounting to $107,093,283, and in the rural districts to $107,991,426. The total urban population is estimated at 42,160,710, and the rural at 43,162,051. The big losses in the cities and villages are not surprising, for in these are located many large buildings filled with millions of dollars worth of property; buildings which are subjected to additional risk because they adjoin one another or are near each other. In the rural districts the buildings are widely separated and contain property that does not compare in value with that in the cities, yet the losses are as great in these districts. The only conclusion that can be drawn from this condition is that the remarkable efficiency of the fire departments of the cities prevents a loss much greater than occurs, and that the absence of fire-fighting apparatus in the rural districts permits the loss in fires to be total.

This fact is plainly shown in the total building loss of the country, the fire departments keeping the loss in cities and villages down to $50,173,625, while fires in the rural districts consumed buildings valued at $58,983,269.

The contents loss in the cities and villages was $56,919,658, as against $49,008,157 in the rural districts; which again proves the contention, in spite of the great loss in the rural districts, as it is well known that the value of the property in city buildings is many times greater than that in buildings in rural communities.

The losses on brick, stone, and steel buildings in cities and villages amounted to $19,816,474, and on contents, $29,092,270; in the rural districts the losses on these buildings were $11,276,213, and on the contents, $8,240,310. The much heavier losses in the cities and villages on the brick, stone, and steel buildings are undoubtedly due to the few buildings of this character in the rural districts in comparison to the number in the cities.

The losses on frame buildings in the cities and villages amounted to $30,357,151, and on the contents to $27,827,388. In the farming communities the losses on these buildings reached a total of $47,707,056, and on the contents $40,767,847. This once more tells of the efficiency of the fire departments in coping with the flames in cities and villages and the utter lack of fire protection in the rural districts.

CAUSE OF FIRE WASTE IN THE UNITED STATES.

The great fire waste in the United States is undoubtedly due to the predominance of frame buildings. In most European cities frame buildings are positively prohibited within the limits of the municipalities, and but few are erected in the rural districts, owing to the scarcity and high price of lumber. In the United States the conditions have been exactly reversed. Lumber, at least until recently, has been the cheaper material, besides being more easily worked than brick, stone, and steel. The result has been that a great majority of the homes of the country and many factory buildings, warehouses, etc., have been made out of lumber.

Of the total losses sustained in the United States in 1907, more than two-thirds were on frame buildings. The exact losses are, $146,659,442 in frame buildings and $68,425,267 in brick, stone, and steel buildings, as shown by the foregoing table.

Another illustration of the influence of frame buildings upon the fire loss of the country is suggested by grouping eleven States which are practically treeless and comparing them with eleven States in which there is still an abundance of timber, the argument being that there will be a greater proportion of frame buildings in the States where lumber is plentiful because of its cheaper price. The States in which there is a supply of lumber show an increased per capita of loss of 59 cents over the per capita of the treeless States, as seen by the following table:

The per capita fire loss for 1907 in 11 States where timber is scarce and in 11 States where timber is plentiful.

[Statistics gathered by United States Geological Survey.]

	Total population.	Total fire loss.	Per capita.
Group 1.—States having scarcity of timber: Iowa, Illinois, Oklahoma, Connecticut, Delaware, New Jersey, South Dakota, Rhode Island, Kansas, Nebraska, and North Dakota	16,785,460	$38,606,558	$2.30
Group 2.—Showing timbered States: Washington, Louisiana, Texas, Mississippi, Wisconsin, Arkansas, Michigan, Pennsylvania, Minnesota, Oregon, and North Carolina	25,569,533	73,895,950	2.89

A study of the fire losses of the United States from the standpoint of geographical division of the States—a division frequently used by the Census Bureau—gives interesting results. The remarkable feature is the per capita loss in the South Central States—Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Texas, Oklahoma, and Arkansas, $3.66—more than $1 in excess of the per capita of any of the other divisions. All of the States in this division have much timber; therefore, many frame buildings. These States also have the handcap of inefficient fire protection compared with the States of the North and East. The total and per capita losses according to geographical divisions of the States are as follows:

The per capita fire losses for 1907 in the United States as shown by geographical divisions of the States.

[Statistics gathered by U. S. Geological Survey.]

Geographical division.	Total population.	Total fire loss.	Fire loss per capita.
North Atlantic: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania	23,779,013	$59,447,532	$2.50
South Atlantic: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida	11,574,988	25,349,223	2.19
North Central: Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas	29,026,645	68,793,148	2.37
South Central: Kentucky, Tennessee, Alabama, Mississippi, Louisiana, Texas, Oklahoma, and Arkansas	16,368,558	59,908,922	3.66
Western: Montana, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, and California	4,783,557	12,676,426	2.65

While the prevailing material of construction—lumber—is largely responsible for the great fire waste of the United States, there is a cause lying back of all of this—faulty construction and equipment of buildings. The list of causes of fires is headed by defective chimneys, flues, fireplaces, and heating and lighting apparatus, all of them faults of construction and equipment. Matches, sparks, and explosions figure prominently in the list, followed by incendiarism, electricity, and lightning. Nearly one-fourth of the fires are labeled "unknown cause," which indicates forcibly the listless attitude toward this waste, not only of the general public, but also of the men directly charged with protecting property against fire—the officials of municipalities and others.

FIRE WASTE IN EUROPEAN CITIES.

In 1905 the Bureau of Manufactures of the Department of Commerce and Labor sent letters of instruction to all the principal United States consular officers in Europe requesting information concerning the fire losses of European cities; also a statement regarding the fire insurance practice in those cities. Unfortunately the statistics gathered were not all for the same year, some cities reporting for 1901, others for 1903, and still others for 1904, a few failing to make any report. It is claimed, however, that there is but little variation from year to year in the fire losses of European cities, and for this reason the figures were tabulated.

Cities of Austria, Belgium, France, Germany, Norway, Russia, Switzerland, and the United Kingdom, with a reporting population of 19,913,916, had a loss of but $9,582,340, a per capita of 48 cents. Russia had the highest loss, $3,100,823, in a population of 2,673,427, a per capita loss of $1.16.

If the United States had Europe's per capita of 48 cents, in a total population estimated by the Census Bureau for 1907 as 85,532,761, the total fire waste in this country for the year would amount to $41,055,725, a saving of natural resources to the extent of $174,028,984.

Taking the maximum per capita in Europe, $1.16 in Russia, and the fire waste in the United States would amount to $99,218,002, or $116,314,759 less than it did.

The principal reason for the great difference between the amount of fire waste in the United States and Europe is that there are but few frame buildings in Europe and practically none in the great cities.

Consul Hossfeld, of Trieste, Austria-Hungary, in his official report to the State Department on the fire losses in the city he represents, said:

> The laws of Trieste and its territory prohibits the construction of wooden buildings. Only sheds and buildings of a temporary nature may be constructed of wood, such as are intended to serve as a shelter for workmen or for the storage of materials while permanent buildings are being constructed.

Consul Harold S. Van Buren, of Nice, France, wrote:

> There may be a few sheds of wood or detached stables of a temporary character, but not sufficient to form a portion of the statistics.

Consul John C. Covert, of Lyons, stated:

> An official in the office of the mayor informed me that there are no wooden buildings in the city, except a few old sheds, constructed without permission and permitted to remain, as they are in open fields and of no danger, being some distance from other buildings.

Consul-General Frank H. Mason wrote concerning Berlin, Germany:

> The comparative immunity of Berlin from disastrous fires, results not from the efficiency of its fire department—although it does promptly and well what

work it has to do—but from the absence of wooden houses and the solid, careful construction of all kinds of stone and brick buildings under the rigid scrutiny of the building police.

The following statement is made in Special Consular Reports, volume 38, Bureau of Manufactures, Department of Commerce and Labor, in discussing the insurance in foreign countries:

In Europe the fire insurance laws are remarkable, chiefly because they compel insurance in some countries, while in all cities they prevent great losses by insisting on the erection of only stone and brick buildings. The fire-department systems are ridiculously inadequate as compared with those of American cities, yet the net results are better. French law compels insurance against fire not only for the benefit of the owner, but for his neighbors. In Germany building insurance is compulsory and in some kingdoms it is a government monopoly. Russia has an elaborate system of central and local government insurance and compels all buildings to be insured. By a law recently enacted the Swiss method of insuring against the loss of time by fire has been made almost impossible. In some of the cantons insurance against loss by fire is compulsory.

The countries of Europe with their reporting city populations and fire losses are as follows:

Fire losses in cities of Europe.

[Statistics gathered by the Bureau of Manufactures.]

Country.	Population.	Fire loss.	Per capita.
Austria [a]	193,387	$72,355	$0.37
Russia [a]	2,673,427	3,100,823	1.16
United Kingdom [a]	4,319,816	1,795,750	.42
Belgium [b]	312,987	178,766	.57
Germany [b]	7,446,447	1,832,402	.25
Norway [c]	222,373	207,000	.93
Switzerland [c]	715,712	192,500	.27
France [d]	4,029,116	2,202,744	.55
Total	19,913,265	9,582,340	.48

[a] Losses for 1904.
[b] Some cities of country report for 1903; others for 1904.
[c] Losses for 1903.
[d] France reports for 1904 with exception of city of Lyon which is for 1901.

Sometime after these statistics were prepared the National Board of Fire Underwriters obtained permission from the State Department to send their own queries to the consular officers in Europe, with the result that figures showing the fire losses in six countries were obtained, some of them for a period of several years. These figures showed the surprisingly low per capita of 33 cents for the six countries, and are as follows:

Fire losses in six European countries.

[Statistics gathered by the National Board of Fire Underwriters.]

Country.	Years.	Fire loss, annual average.	Population 1901.	Loss per capita.
Austria	1898–1902	$7,601,389	26,150,597	$0.29
Denmark	1901	660,924	2,588,919	.26
France	1900–1904	11,699,275	38,595,500	.30
Germany	1902	27,655,600	56,367,178	.49
Italy	1901–1904	4,112,725	32,449,754	.12
Switzerland	1901–1905	999,364	3,325,023	.30

Or an average loss per capita of $0.33.

EUROPEAN AND AMERICAN LOSSES COMPARED.

Another comparison, which is perhaps even more interesting as illustrating America's needless waste and Europe's prudence, is given in the following table of per capita loss in cities of the United States and Europe, arranged in classes according to their populations:

Per capita fire losses in American and European cities, classified according to population.

[Statistics for the United States gathered by the Geological Survey, and for Europe by the Bureau of Manufactures.]

	Per capita loss, United States, 1907.	Per capita loss, Europe.
Cities over—		
300,000	$2.24	$0.65
100,000 to 300,000	2.14	.37
50,000 to 100,000	2.47	1.67
30,000 to 50,000	3.28	.72
10,000 to 30,000	2.37	.81
Under 10,000	3.47	....

FIRE LOSSES IN CITIES OF EUROPE AND AMERICA OF EQUAL SIZE.

Comparing American and European cities of the same size, and the following per capita losses are found:

Fire losses in American and European cities of the same size.

[Statistics gathered by U. S. Geological Survey and Bureau of Manufactures.]

European losses for 1904.				United States losses for 1907.			
	Population.	Fire loss.	Per capita.		Population.	Fire loss.	Per capita.
Paris, France	2,714,068	$1,266,282	$0.47	Chicago, Ill	2,049,185	$3,937,105	$1.43
Frankfort, Germany	324,500	99,492	.31	Cincinnati, Ohio	345,230	1,971,217	5.70
St. Petersburg, Russia	1,500,000	2,128,541	1.42	Philadelphia, Pa	1,441,735	2,093,522	1.45
Birmingham, England	550,000	226,506	.41	Baltimore, Md	553,669	916,603	1.66
Sheffield, England	426,686	75,989	.18	Cleveland, Ohio	460,000	515,194	1.12
Toulon, France	101,602	55,391	.55	Atlanta, Ga	104,984	225,237	2.15
Bremen, Germany	203,847	78,372	.38	St. Paul, Minn	204,000	522,447	2.56
Molenbeek, Belgium	63,678	106,150	1.67	Evansville, Ind	63,957	196,702	3.08
Lalken, Belgium	31,121	22,349	.72	Oshkosh, Wis	31,033	80,500	2.59
Etterbeck, Belgium	23,992	19,504	.81	Easton, Pa	25,238	32,073	1.27

CONFLAGRATIONS.

Since the year 1866 the conflagration losses in the United States have totaled the sum of $936,551,135, according to the tabulation made by the National Board of Fire Underwriters. By conflagration is meant all fire involving a loss of half a million dollars and over.

The conflagrations of 1907 cost the United States $18,475,000, according to the same authority.

The year 1908 promises to exceed the conflagration loss of the preceding year, one conflagration alone, that at Chelsea, Mass., on April 12 and 13, involving an insurance loss of $8,846,879, as reported by the underwriting companies to the Massachusetts insurance commissioner.

The notable conflagrations of the United States were those at Chicago, in 1871; Boston, 1872; Baltimore, 1904; and San Francisco on April 18, 1906. The earthquake and fire at San Francisco resulted in a total property loss of $350,000,000, exceeding in amount any previous similar disaster in the history of the world.

The fact that no other country suffers such enormous conflagration losses has led to a general investigation of the causes by fire underwriters, fire marshals, officials of States and municipalities, and students of economic conditions, and the conclusion has been that poor and defective construction of buildings and equipment are responsible. The investigation has further disclosed that an increase in the number and severity of conflagrations may be expected until there is a decided improvement in the methods of construction.

The danger of conflagration is present in every city and village of the United States, and with it the possibility of large loss of life. The most efficient fire department in the country is powerless when once a fire gets considerable headway in a locality where bad construction prevails.

The Ohio fire marshal, in his annual report for 1907, in urging new building codes for Cleveland and Cincinnati, the two largest cities of the State, says: "Either city may at any time suffer a conflagration costing $300,000,000."

The October, 1908, Quarterly of the National Fire Protective Association, on the subject of better buildings, says:

> The average American city is full of fire traps. Buildings of great area, without fire cut-offs, with large floor openings, with unprotected windows, and with very combustible contents are too numerous to prove the exception to any rule. These are conflagration breeders. Fire travels through these buildings rapidly and under certain conditions can get beyond even the best fire department, and sweeping through the unprotected windows of surrounding buildings will soon cause a conflagration.

LIVES LOST IN FIRES.

During the year 1907 fires caused the death of 1,449 persons and the injury of 5,654, according to the information gathered by the United States Geological Survey. These figures are incomplete and perhaps do not represent more than half the persons who were victims of fires. Many fire chiefs of large cities failed to report any deaths, because such were not properly included in their annual reports. The cause of this again is faulty construction in buildings—in many instances lack of appreciation on the part of cities of the responsibility to safeguard the lives of their citizens or ignorance of what is demanded to protect against fires.

The Iroquois fire in Chicago, December 30, 1903, in which 600 persons lost their lives, was a terrible object lesson in bad construction and equipment, yet this was not sufficient to stop these disasters. January 13, 1908, fire in an opera house at Boyertown, Pa., cost the lives of nearly 200 women and children. Two months later, March 4, 165 children were burned to death in a schoolhouse at Collinwood, Ohio. With proper construction of buildings none of these lives would have been lost.

SUMMARY.

The capital investment and the annual maintenance cost making up loss and expense on account of fire losses, fire protection, cost of waterworks chargeable to conflagration service, maintenance of fire departments and private fire-fighting devices are summarized in the following table.

Capital invested for fire protection and annual loss and expense on account of fire (United States, 1907.)

Annual loss and expense:		
Total fire loss		$215, 084, 709
Fire protection—		
Amount of fire-insurance premiums paid above amount of losses paid		[a] 145, 604, 362
Total annual expense of waterworks chargeable to fire service—		
Depreciation and taxes	4, 603, 731	
Interest charge	[b] 9, 826, 867	
Maintenance	8, 465, 487	
		28, 856, 235
Total annual expense of fire departments—		
Depreciation and taxes	4, 603, 731	
Interest charge	[c] 4, 282, 540	
Maintenance	40, 054, 574	
		48, 940, 845
Total annual private fire protection		18, 000, 000
Total annual loss and expense		456, 486, 151
Investment in construction and equipment:		
Total cost of waterworks (construction and equipment) chargeable to fire service—		
Source of water supply	$66, 482, 220	
Distributing system (2,016,927 tons of metal)	127, 236, 668	
Hydrants (350,152)	29, 761, 400	
Separate high-pressure fire service	22, 191, 388	
		[d] 245, 671, 676
Total cost of fire departments (construction and equipment)		107, 063, 524
Total cost (construction and equipment) of private fire extinguishers, automatic sprinklers, etc		50, 000, 000
Total investment in construction and equipment		402, 735, 200

A study of this table shows that 22 per cent of the total expenditure on behalf of public water supplies is due to additional supplies necessary for protection against fires of such magnitude as may be propagated beyond the building of origin. It will be incidentally noted that there are 2,000,000 tons of metal, having a value in excess

[a] The amount paid by insurance companies on account of fire loss was $114,164,469, and the amount received by them in premiums was $259,768,831.

[b] $245,671,676, cost of waterworks, chargeable to fire service, capitalized at 4 per cent interest, is equal to an annual charge of $9,826,867.

[c] $107,063,524, cost of fire departments, capitalized at 4 per cent interest, is equal to an annual charge of $4,282,540.

[d] This is 22 per cent of the total cost of water systems, domestic and fire service combined.

of $127,000,000, and the metal in 350,000 hydrants, having a value of nearly $30,000,000, all of which is wasted on account of the need of preparation to fight fires of a kind which, because of the inflammable character of building construction in this country, would develop into conflagrations without adequate water service and fire departments.

The annual cost of maintenance of fire departments in European cities is set forth in the following table, from which it is apparent that the average annual cost in European cities is 20 cents per capita. Compared with this, the average cost in cities in the United States having a corresponding population of 100,000 and over and an aggregate population closely approximating that of these European cities, shows a per capita cost of $1.53, or seven and one-half times the cost of public fire protection over and above that found necessary in Europe.

Annual cost maintenance of fire departments in European cities.

City.	Population.	Fire department maintenance.	Per capita.
Kiel and suburbs	171,000	179,002m. = $42,602	$0.25
Cologne and suburbs	458,037	509,609m. = 121,286	.26
Berlin	1,888,848	2,035,346m. = 484,412	.26
Breslau	422,738	465,571m. = 110,805	.26
London	6,580,616	254,045 £.=1,238,469	.19
St. Petersburg	1,313,300	578,503 r. = 295,036	.22
Paris	2,714,068	2,925,334 f. = 564,589	.21
Stockholm	311,043	269,164K. = 72,135	.23
Budapest	723,322	281,544K. = 57,123	.08
Milan	491,460	431,253 l. = 83,231	.17
Total	15,074,432	3,069,688	[a].20
Cities in United States having population of 100,000 and over.	16,883,435	25,754,386	1.53

[a] Average.

It is reasonable to assume that at such time as building construction in the United States, through the materials used, building codes adopted, and the enforcement thereof, shall have reached a condition similar to that in Europe our annual costs for this one item alone may be reduced from more than $25,000,000 to $3,000,000, or to less than one-seventh of the present total.

It will be noted that the per capita cost in this country and in Europe which make up these total figures are nearly equally divided between the fire losses and the annual expense of fire protection, and that the ratio of these in the United States and in Europe is nearly the same.

NATIONAL VITALITY, ITS WASTES AND CONSERVATION.

By Irving Fisher,
Professor of Political Economy, Yale University.

ACKNOWLEDGMENTS.

The materials upon which this report is principally based were collected during the last ten years. They are far from complete, and I had expected to make use of them at my leisure for a series of special articles, but the opportunity which suddenly presented itself of utilizing them in the construction of this report was one which could not be resisted, despite the fact that the time available was only three months. In the endeavor to make the best use of this time I have been compelled in some cases to rely on secondary sources of information. The number of such cases has been greatly reduced, however, through the kindness of colleagues, friends, and correspondents who were appealed to for suggestions, criticisms, and supplementary material. I am greatly indebted to Prof. Lafayette B. Mendel, of the Sheffield Scientific School of Yale University, for helpful comments and detailed criticism of the whole report, and especially of those parts relative to the physiology of nutrition; to Prof. Yandell Henderson, for many helpful suggestions; to Prof. Henry W. Farnam, for suggestions regarding the topics of industrial conditions; to Prof. M. V. O'Shea, of the University of Wisconsin, for carefully revising the major part of the section on school hygiene; to Dr. Charles Wardell Stiles, Chief of the Division of Zoology, Hygienic Laboratory, United States Public Health and Marine-Hospital Service, for information on the extent and burden of the hook-worm disease; to Surg. Gen. Robert M. O'Reilly, of the United States Army, for statistics of army hygiene; to Dr. Prince A. Morrow, of New York City, and to Prof. C. R. Henderson, of the University of Chicago, for carefully prepared notes in regard to "the social evil."

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To the help received from these persons will be due in large measure whatever of value this report may have. I could not, single-handed, have done justice to even a portion of the subject. Except for a few statistical monographs and papers cited in it, I have contributed little original material. It has been my task to interpret material brought together from many sources. Despite all the aid received, I am aware that the report abounds in sins of omission. Great pains have been taken to avoid those of commission. Doubtful material has been eliminated so far as possible, and where exact figures were unobtainable, every effort has been made to see that the statements made should be cautious and conservative.

For aid in the difficult work of incorporating into the manuscript the numerous suggestions received, I am indebted to Profs. J. Pease Norton, William B. Bailey, Fred R. Fairchild, and Dr. L. W. Zartman, of the economic department of Yale University; and to Dr. M. M. Scarborough, of the Yale Medical School, and Dr. F. B. Standish, of New Haven. For criticisms on the form of presentation, I am indebted to Mr. Edwin Bjorkman, of New York City; to Mr. Michael Williams, of Oak Bluffs, Mass.; and to Mr. Herbert A. Smith, of the U. S. Forest Service.

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IRVING FISHER.

YALE UNIVERSITY, *November, 1908.*

SUGGESTIONS FOR READERS.

In order that this report may be read and used as widely as possible, it has been arranged with reference to five classes of readers:

1. The "Contents by sections," the index, and the page headings will facilitate the use of the report for reference purposes.
2. The "Abstract" is chiefly intended for those who have no time to read more.
3. The "Summary" is a somewhat fuller résumé.
4. The "Summary" is also designed to enable those who so desire to read some parts of the report more fully than others. To this end the "Summary" is arranged to correspond to the main report, chapter by chapter and section by section. The reader who, after reading any particular part of the "Summary," wishes to read the corresponding part of the main report has only to turn to the chapter or section having the same number.
5. Those who read the entire report will probably prefer to read the "Summary" or "Abstract" last.

ABSTRACT.

The problem of conserving natural resources is only one part of the larger problem of conserving national efficiency. The other part relates to the vitality of our population. The two parts are closely interwoven. Protection against mining accidents, forest fires, floods, or pollution of streams prevents not only loss of property, but loss of life. The prevention of disease, on the other hand, increases economic productivity.

So far as we can compare vital and physical assets as measured by earning power, the vital assets are three to five times the physical. The facts show that there is as great room for improvement in our vital resources as in our lands, waters, minerals, and forests. This improvement is possible in respect both to the length of life and to freedom from disease during life.

Contrary to common impression, there is no iron law of mortality. Recent statistics for India show that the average duration of life there is less than twenty-five years. In Sweden it is over fifty years, in Massachusetts forty-five years. The length of life is increasing wherever sanitary science and preventive medicine are applied. In India it is stationary. In Europe it has doubled in three and a half centuries. The rate of increase during the seventeenth and eighteenth centuries was about four years per century, during the first half of the nineteenth century about nine years per century, during the latter half of the nineteenth century about seventeen years per century, and in Germany, where medical and sanitary science has reached the highest development, about twenty-seven years per century. The only comparative statistics available in this country are for Massachusetts, where life is lengthening at the rate of about fourteen years per century, or half the rate in Germany.

There is no need, however, of waiting a century for this increase. It could be obtained within a generation. Three-fourths of tuberculosis, from which 150,000 Americans die annually, could be avoided. Eighteen experts in various diseases, as well as vital statisticians, have contributed data on the ratio of preventability of the ninety different causes of death into which mortality may be classified. From these data it is found that fifteen years at least could be at once added to the average human lifetime by applying the science of preventing disease. More than half of this additional life would come from the prevention of tuberculosis, typhoid, and five other diseases, the prevention of which could be accomplished by purer air, water, and milk. In Lawrence, Mass., after the installation of a pure-water supply, the death rate from typhoid was reduced by 80 per cent. For every death thus saved from typhoid, two or three deaths are saved from other diseases.

Judging from the English statistics of illness, we must conclude that at all times in the United States about 3,000,000 persons are seriously ill, of whom about 500,000 are consumptives. Fully half of this illness is preventable.

If we appraise each life lost at only $1,700 and each year's average earnings for adults at only $700, the economic gain to be obtained from preventing preventable disease, measured in dollars, exceeds one and a half billions. This gain, or the lengthening and strengthening of life which it measures, can be secured through medical investigation and practice, school and factory hygiene, restriction of labor of women and children, the education of the public in both public and private hygiene, and through improving the efficiency of our municipal, state, and national health service. Our National Government has now several bureaus exercising health functions, which only need to be concentrated under one department to become coordinated parts of a greater health service worthy of the nation.

SUMMARY.

Summary of Part I.—*Length of life versus mortality.*

SUMMARY OF CHAPTER I—THE LENGTH OF LIFE.

Section 1. *In different places.*—President Roosevelt has pointed out that the problem of conserving our natural resources is part of another and greater problem—that of national efficiency. This depends not only on physical environment, but on social environment, and most of all on human vitality. Modern hygiene is the reaction against the old fatalistic creed that deaths inevitably occur at a constant rate. The new motto is that of Pasteur: "It is within the power of man to rid himself of every parasitic disease."

It was once believed that human mortality followed an "inexorable law." Facts, however, show that mortality varies in different places and is decreasing as hygiene comes into use. The leugth of life in Sweden and Denmark is over fifty years; in the United States and Englaud about forty-five; in India less than twenty-five.

Sec. 2. *At different times.*—In Europe, according to one authority, the length of life has increased in three hundred and fifty years from less than twenty to about forty years; in England, in less than half a century, it has increased about five years; in Prussia, in the last quarter of a century, over six years; in America it has also increased, although good life tables are lacking excepting for insurance experieuce. The tables for Massachusetts for 1893–1897 show an average duration of life in that State of forty-five years, as compared with forty in 1855, and thirty-five, an estimate of 1789, based, however, on doubtful returns.

SUMMARY OF CHAPTER II—THE MORTALITY RATE.

Section 1.—*Relation of longevity to mortality.*—As duration of life increases the death rate decreases. A death rate is the ratio of the numher of deaths in a year to the population. Under normal conditions where the population is "stationary"—that is, neither increasing nor decreasiug nor subject to immigration or emigration—the death rate and the duration of life are "reciprocals." In such a population, if the death rate is 20 per 1,000, the duration of life will be $1,000 \div 20 = 50$ years.

This relation, however, is disturbed in most countries to-day, and especially in America, by immigration and emigration and by the birth rate being in excess of the death rate. Nevertheless, death rates, if compared under similar conditions, furnish a fairly good index of vitality. They vary in different places and at different times.

Sec. 2. *Mortality in various regions.*—In the registration area of the United States the death rate is 16.5 per 1,000; in France it is 20; in India 42. In different States of the United States it varies from 14 in Michigan to 18 in New York.

Sec. 3. *Urban and rural mortality.*—The death rate is higher in the city than in the country, and the larger the city the higher the death rate. In European countries among the cities with the highest death rate are Dublin (40) and Moscow (37); among the lowest, Frankfort on the Main (16) and The Hague (16).

Sec. 4. *Raee and condition.*—The colored death rate greatly exceeds the white. The death rate among the poor exceeds that among the rich, being in Glasgow and Paris over twice as great.

Sec. 5. *Mortality historically.*—Death rates have been decreasing during several centuries. In London, where now the death rate is only 15, it was during the seventeenth and eighteenth centuries 40 to 50, and during 1680 to 1728, a period of pests, it rose as high as 80. Similar reduction has also been experienced in this country. In Habana the death rate after the American occupation fell from over 50 to about 20.

SEC. 6. *Adult and infant mortality.*—The greatest reduction has been effected among children, although the death rate is still undoubtedly high. Statistics show that during the last thirty years the death rate up to 50 years of age has decreased, but that beyond 50 it has remained almost stationary.

SEC. 7. *Particular diseases.*—The mortality from certain special diseases has greatly decreased. The tuberculosis death rate is now in England only one-third of what it was seventy years ago. The death rate from pneumonia now equals that of tuberculosis. Typhoid fever is decreasing. Iu Munich during 1856 the mortality was 291 per 100,000 of population. The city at that time contained many cesspools. After these were filled up the typhoid rate fell to 10 per 100,000 in 1887, making a reduction of 97 per cent. In Lawreuce, Mass., after the public water was filtered in 1893 the typhoid-fever rate fell from 105 to 22. Doctor Kober has shown that death rates from typhoid fever are greatest in cities in which the rivers' waters are polluted, the average for these cities being 62, as compared with 18 for cities using unpolluted water of impounded and conserved streams. Doctor Rosenau concludes that any community having clean water and uninfected milk supply may be free from typhoid.

Smallpox has greatly decreased since vaccination has been employed. In Prussia the death rate per 100,000 from smallpox between 1846 and 1870 was 24. In 1874 vaccination was made compulsory, and the death rate for the years 1875–76 fell to 1.5. Similar figures can be given for other places. The present outcry against vaccination is based on misinformation and on the general reasoning that it is unnatural to introduce a poison into the blood. Statistics show clearly that vaccination decreases smallpox and lengthens life. Even though it were shown that the virus is injurious, it would be the lesser of two evils.

Yellow fever in Philadelphia in 1793 caused the death of one-tenth of the city's population within six and one-half weeks. In 1900 it was found that a species of mosquito transmits this disease. The result of this applied knowledge is that the disease has practically disappeared in America.

SUMMARY OF PART II.—*Breadth of life versus invalidity.*

SUMMARY OF CHAPTER III—PREVALENCE OF SERIOUS ILLNESS.

SECTION 1. *Loss of time.*—Life is shortened by death and narrowed by invalidity. The ideal life, with respect to health, would be free from illness and disability of every kind. To approximate such an ideal is the aim of hygiene. It is usually true that the healthier a life the longer it will last. Humboldt maintained that he had lived four working lives by retaining a working power double the average for double the average number of years. According to Farr, for every death there is an average severe sickness of two years, or for each death per year there are two persons sick throughout the year. This would mean in the United States that, as there are about 1,500,000 annual deaths, there will always be about 3,000,000 persons on the sick list, which is equivalent to about thirteen days per capita.

SEC. 2. *Particular diseases.*—There are constantly ill in the United States of tuberculosis about 500,000 persons, of whom about one-half are totally incapacitated, while the remainder are half incapacitated. The causes of various diseases are closely interwoven. Professor Sedgwick tells us that "Hazen's theorem" shows for every death from typhoid fever avoided by the purification of a polluted water supply two or three deaths are avoided from other causes. Hook-worm disease in the South is a chief cause of incapacitation, especially among the poor whites. For this reason the hook worm has been nicknamed the "germ of laziness." It is believed that a sufferer from hook-worm disease is incapacitated from one-fourth to one-half of the time.

The number of syphilitics in the United States has been estimated at 2,000,000, though from the nature of the case this figure is chiefly coujecture. The social diseases, syphilis and gonorrhea, are responsible for the existence of a large proportion of defectives of various kiuds which fill our institutions. Among the troops in the Philippines the venereal morbidity, during the year 1904, was 297 per 1,000, largely exceeding the morbidity from malarial fevers and diarrhea, as 22 out of every 1,000 soldiers were constantly ineffective from venereal disease—four times as many as from any other disease. The statistics outside of army and navy service are impracticable, but there is some reason to believe that they might show an even larger morbidity. The social diseases, which certainly are preventable, are one of the gravest of the menaces to national efficiency.

American railways in 1907–8 killed nearly 11,800 and injured nearly 111,000 persons. The deaths and disablements from accidents in industry, although less carefully recorded, also represent a great and needless impairment of efficiency.

SUMMARY OF CHAPTER IV—PREVALENCE OF MINOR AILMENTS.

SECTION 1. *Importance of minor ailments.*—Minor ailments are far more common than most persons realize. They are chiefly functional disorders, such as of the stomach, heart, nerves, liver, kidney, etc. These deserve more attention than they have hitherto received, because they are the gateway to more serious troubles. For instance, those who neglect colds, or what seem to be colds, will be far more likely to become victims of tuberculosis or pneumonia. No statistics of the prevalence of minor ailments exist. Physicians, whose experience gives them good opportunity to judge, place the time lost annually for each person from minor ailments at three or more days a year.

SEC. 2. *Preventability of minor ailments.*—Practically all minor ailments can be avoided by proper hygiene, public and private. Neurasthenia, so common in America, is one of the most serious and insidious introductions to grave disorders, and is usually due to needless worry or failure to have adequate recreation.

SUMMARY OF CHAPTER V—PREVALENCE OF UNDUE FATIGUE.

SECTION 1. *Strength, endurance, and fatigue.*—Strength is measured by the force a muscle can exert once; endurance by the number of times it can repeat an exertion requiring a specified part of the strength. Fatigue is a chemical effect, due to "fatigue poisons." Far greater differences exist between different persons in respect to endurance than in respect to strength. Some "well" people become tired by a short walk, while others withstand hours of walking, running, or climbing.

SEC. 2. *Alcohol and fatigue.*—The "Committee of Fifty" found that alcohol gives no persistent increase of muscular power. It is well understood by all who control large bodies of men engaged in physical labor that alcohol and effective work are incompatible. Rivers, writing on the influence of alcohol on fatigue, found that when workmen were provided with a moderate amount of wine it resulted in a considerable diminution of their capacity for work.

SEC. 3. *Tobacco and fatigue.*—Athletes recognize that smoking interferes with one's "wind" or "staying power." "Inhaling" tobacco smoke brings carbon-monoxide directly into the blood stream. It is found that smoking increases blood pressure, which fact possibly partly explains the reduction in endurance.

SEC. 4. *Diet and fatigue.*—When excessive amounts of the protein element in food (exemplified in white of egg or the lean part of meat) are taken, they putrefy in the large intestine, producing "auto-intoxication." For this and other reasons, there is a present tendency among physiologists to advise a reduction in the use of such foods from the amounts customary in many countries, and especially in the United States. Auto-intoxication induces fatigue. The endurance of those using high protein and of those using low protein shows in general, although with some exceptions, that the former have less endurance than the latter. Whether the latter are vegetarian or not does not seem to matter. Experiments show that thorough mastication leads instinctively to a reduction in protein.

SEC. 5. *Exertion and fatigue.*—Oxygen, whether taken naturally or artificially, increases the capacity for exertion. A judicious amount of exercise is perhaps the chief factor in producing the highest state of muscular efficiency. Physical training, comprising exercise and other hygienic measures, will probably make the capacity to withstand great exertion three or four times that possessed by most persons.

SEC. 6. *The working day.*—The present working day, from a physiological standpoint, is too long, and keeps the majority of men and women in a continual state of overfatigue. It starts a vicious circle, leading to the craving of means for deadening fatigue, thus inducing drunkenness and other excesses. Experiments in reducing the working day show a great improvement in the physical efficiency of laborers, and in many cases results in even increasing their output sufficiently to compensate the employer for the shorter day. Several examples of such a result exist, but the real justification for a shorter work day is found in the interest of the race, not the employer. One company, which keeps its factory going night and day, found, on changing from two shifts of twelve hours each to three shifts of eight hours each, that the efficiency of the men gradually increased, and the days lost per man by illness fell from seven and one-half to five and one-half per year. Public safety requires, in order to avoid railway collisions and other accidents, the prevention of long hours, lack of sleep, and undue fatigue in workmen.

Sec. 7. *The importance of preventing undue fatigue.*—The economic waste from undue fatigue is probably much greater than the waste from serious illness. This is because the number of fatigued persons is great enough to more than outweigh the fact that the incapacitation from fatigue is relatively small. Moreover, the relatively slight impairment of efficiency due to overfatigue leads to greater impairment from serious illness. A typical succession of events is, first, fatigue, then "colds," then tuberculosis, then death. The prevention of undue fatigue means the arrest at the start of this accelerating chain of calamities.

Summary of Part III.—*Methods of conserving life.*

SUMMARY OF CHAPTER VI—CONSERVATION THROUGH HEREDITY.

Section 1. *Heredity and environment.*—A wise and farsighted economy will lead the nation to conserve its vital resources by every possible method. These resources depend on two primary conditions, heredity and hygiene, or conditions preceding birth and conditions during life. In other words, vitality is partly inherited and partly acquired. A sound physical and mental inheritance is a greater asset than the inheritance of extraneous advantages like wealth. Even in the Old World a degenerate nobility in the end receives less respect than a virile middle class. The effort to improve vitality reaches its highest point in a nation when its health ideals affect marriage.

Sec. 2. *Eugenics.*—Galton, Pearson, and others are attempting to found the new science of "eugenics," by which is not meant any scheme of general governmental interference with marriage, but the gradual establishment in public opinion of fundamental standards. Just as to-day the marriage of brother and sister is unthinkable, Galton suggests that the time may come when marriage which obviously promotes degeneration will be equally tabooed. The result would be, not to make marriage more artificial, but less. Health, beauty, and vitality are much more natural objects of youthful admiration than titles or wealth, which now exercise, for the most part, a baneful influence on marriage. To lessen the esteem for those false attractions and increase that for natural attractions will tend not only to increase the number of healthy marriages, but to give greater importance to natural and normal love. The effect will be felt both in bringing about a larger proportion of marriages among the healthy and a smaller proportion among the unhealthy. It will also lead to a partial segregation by which the healthy will to a large extent marry among themselves, and thus leave the unhealthy either unmarried or compelled to make alliances in their own class. The result will be, in the struggle for race supremacy, that the healthy, thus separated off from the relatively unfit, will have a distinct advantage both in the number of offspring and in their vitality.

Sec. 3. *Eugenics and law.*—The only government influences which have been seriously suggested by eugenists are two: First, the offering of prizes or bounties to couples who conform to certain standards, in the same way as the French Government has encouraged the increase of its population by offering inducements to couples of the poorer class who raise seven or more children; second, to prevent marriage alliances among criminals, paupers, and the feeble-minded. Some laws on these subjects already exist in Connecticut, Michigan, and especially Indiana, where there is a prohibition of marriage of all persons suffering from transmissible diseases. It is also now provided in Indiana that confirmed criminals, imbeciles, and rapists, when it is deemed advisable by experts, shall be unsexed. What such laws might accomplish may be judged from the history of two criminal families, the "Jukes" and the "Tribe of Ishmael." Out of 1,200 descendants from the founder of the "Jukes" through seventy-five years, 310 were professional paupers, who spent in all two thousand three hundred years in poorhouses, 50 were prostitutes, 7 murderers, 60 habitual thieves, and 130 common criminals. The loss of potential usefulness, cost of prosecutions, expense of maintenance of jails, etc., Dugdale estimated to be $1,300,000 in seventy-five years, or over $1,000 for each member of the family. All these unfortunate results could have been avoided had the original criminals in this family been sterilized under a law like that of Indiana.

We have the more agreeable record of excellent human qualities inherited through successive generations in the Darwin, Hohenzollern, and other families.

SUMMARY OF CHAPTER VII—CONSERVATION THROUGH PUBLIC HYGIENE.

SECTION 1. *Municipal hygiene.*—The benefits of improved heredity can be enjoyed only by future generations. But we of the present day may conserve our vital resources through hygiene, practiced in one or all of three ways—public, semipublic, and personal hygiene. The first refers to governmental regulation of health, the second to the professional or institutional care of health, and the third to the private life of the individual and the family. Every city now has its health board, yet few citizens realize that the protection rendered by these boards is more important than the protection by the police or fire departments. Much as is done by these boards, there is enormous room for improvement, both in making regulations and in enforcing them by the aid of a more enlightened public opinion. The abatements of the nuisance and menace from spitting and from vitiation by smoke are cases in point. Pure air is one of the primary necessaries of life, but only a small fraction of our countrymen actually enjoy this boon. To this end proper drainage and garbage removal and clean streets are needed. The transmission of disease by insects, flies, and vermin needs to be checked. A constant cause of mortality, among infants especially, is an impure milk supply. The same danger exists in other dairy products, cream, butter, cheese, and ice cream. In Washington, owing apparently to the enactment of a law in 1895 regulating the sale of milk, the death rate from diarrhea and inflammation of the bowels among children under 2 years of age was reduced from 160 or 170 to 135, then 109, 104, and in 1906 to 97. Similar reports come from many other cities in this country and abroad.

SEC. 2. *State hygiene.*—The regulation of the labor of women and children is usually a state matter. It has been suggested by Doctor Stiles that every woman should be allowed once a month to leave a factory without being asked questions or losing wages. The employment of mothers before and after childbirth should be prohibited, as it is now in a number of European countries. This single reform would help greatly to conserve the vitality of the next generation. Child labor in the South is in many cases the lesser of two evils, the other being exposure to the hook-worm disease on polluted farms. In these cases, the abolition of child labor should be preceded by the abolition of hook-worm disease. Hours of labor have been steadily decreasing, and should be decreased further. Accidents are unnecessarily frequent on our American railroads, as well as in industrial establishments. Statistics do not exist for the latter. Special trades have special dangers. Among such trades are those using lead and other dangerous poisonous chemicals, as well as the dust-producing trades which tend to pulmonary troubles. The dark room tenements are a common means in our large cities of depleting national vitality.

SEC. 3. *Federal hygiene.*—This includes quarantine, the inspection of immigrants and exclusion of those with infectious diseases, administration of government hospitals, of pure-food laws and meat inspection, and cooperation with state boards of health in fighting yellow fever, bubonic plague, etc. Federal power needs extension, however. Our interstate railroads should be improved in respect to the sanitation of sleeping cars, smoking cars, etc.

The movement to secure a more intelligent national organization of health is now beiug pushed by the President, President-Elect, and Members of Congress, and has found expression in the recent platforms of both political parties. What is needed is that the Federal Government should make the national capital a model of sanitation, should provide for more investigation in health matters and the dissemination of information on the prevention of tuberculosis, etc., should cooperate further with state and municipal authorities, and should check the pollution of interstate streams and prevent the transmission of disease-bearing meats or other food from one State to another. Lastly, it should secure, through whatever constitutional means exist, some method of collecting statistical information as to our national mortality and morbidity. Our shortcomings in this respect are now a national disgrace. There is no accurate record of births in any part of the United States, and that of deaths includes less than half our population. As a statistician has said of one of the States, "It buries its dead people with no more ceremony than it buries its dead dogs." Obviously, no intelligent control of epidemics and other diseases can be made unless the facts in regard to those diseases are known; in other words, unless there exist mortality and morbidity statistics of real value.

SUMMARY OF CHAPTER VIII—CONSERVATION THROUGH SEMIPUBLIC HYGIENE.

SECTION 1. *Medical research and instruction.*—Semipublic hygiene comprises that relating to institutions and the medical profession. The hygiene of the future must depend more on discoveries in preventive medicine than on any other single factor, and institutions such as the Pasteur Institute, the Rockefeller and the Carnegie institutes, and the research laboratories of the Government and universities offer the most promising means of increasing this most useful and practical of all human knowledge. The knowledge is dispensed through medical schools in the training of physicians. These schools are improving so as to introduce more of hygiene and preventive medicine. We are still far, however, from having facilities for training public health officers, or giving them such a degree as D. P. H. (diploma of public health), as is given in England.

SEC. 2. *The medical profession.*—Antiseptic surgery has in the last century been the greatest triumph of the medical profession, and has given it a greater prestige than ever before. It has greatly reduced the mortality from operations, and is illustrated by the figures in army operations. The mortality of the wounded in the Crimean war among English troops was 15 per cent. The mortality in the Transvaal war, 1900–1901, was less than 6 per cent.

In the practice of medicine, the tendency is progressively to give up the use of violent drugs and to depend more on hygiene. Through the modern fight against tuberculosis, physicians have come to prescribe fresh air in their practice generally. They are now turning in like manner to exploit the resources of diet, exercise, bathing, and mental hygiene.

There is danger that these new fields will be preempted by quacks. Many quacks to-day, far from using patent medicines, oppose the use of any drugs whatever. In order that modern hygiene shall be applied by trained physicians, it is necessary that they provide more facilities in this direction. The leaders of the profession are making every effort to raise all members of their profession to their own high standard. This standard not only aims to prevent malpractice and unethical operations, but to set an example to the people in public service and in personal hygienic living.

SEC. 3. *Institutional hygiene.*—Hospitals have done much to prevent disease by segregating infectious cases. Institutions for the deaf and blind and other defectives have led to a better utilization of their powers. Institutional care of the insane has done much, too, but can do more. Mental hygiene as a whole needs to be more carefully studied and taught in all its relations—heredity, alcohol, syphilis, and environment.

The modern sanitarium has become a useful institution for prevention of serious illness, as distinct from the hospital, of which the function has been to cure. Department stores, hotels, and other commercial institutions are installing ventilating and other hygienic apparatus. The churches are also taking part in the health movement, especially the Emmanuel Church in Boston.

SEC. 4. *School hygiene.*—The hygiene of school children is especially important because of its application to human life in its early stages. There is a world-wide movement, led by Switzerland and some other countries of Europe, to obtain and apply knowledge of how to educate the mind without weakening the body. As it is, school children are especially exposed to contagious diseases, which under present conditions often sweep through a whole school before the local health board even hears of it. Quite as serious, if not more so, is the protecting of school children from imperfect seating, lighting, ventilation, and sanitation.

Backward children, with defects of eye, ear, nose, or throat, are numerous, but experiments have shown that the majority could be improved both in intellect and in morals.

In respect to school hygiene, it is not so much lack of knowledge as lack of application of knowledge which is at fault. In order to find and then correct defects of eyes, ears, teeth, etc., and properly apply our knowledge, medical inspection is necessary. Such inspections as have been made disclose an astonishing amount of ill health, the percentage of morbidity being from 20 to 60 per cent. The committee on physical welfare of school children in New

York found that 66 per cent needed medical or surgical attention or better nourishment; 40 per cent needed dental care; 38 per cent had enlarged glands of the neck; 31 per cent had defective hearing; 18 per cent had enlarged tonsils.

Eye strain is a particular evil of civilization, and makes its first appearance in school when the scholar tries to accommodate the eye to the short range which reading requires, but for which the eye mechanism is not well adapted by nature. The evil effects of eye strain are not confined to that organ, but extend to the whole nervous system, and indirectly to the whole organism. Doctor Gould, who has made a special study of this subject, goes so far as to maintain that "eye strain is the chief source of the functional diseases of our citizens."

At present medical inspection is the exception rather than the rule. Only 70 cities in the United States outside of Massachusetts, and 32 cities and 321 towns in Massachusetts, have systems more or less complete. New York employs 150 physicians, who visit each public school once a day to examine children set aside for that purpose by the teacher. In Providence a fresh-air school for children suffering from tuberculosis has been established. The cost of the school per capita is about 50 per cent more than the ordinary schools, but the results justify the expenditure.

Our scholars are being seriously injured by nervous overstrain. Probably this is not because too much work is being required, but because the performance of this work is not accomplished economically. Some experiments seem to indicate that children could accomplish as much intellectually with far less dissipation of nervous energy if they were in the schoolroom about half of the time now spent there. High pressure and long hours are bad economy in schools as in factories.

Playgrounds conserve child vitality and are far superior to formal gymnastics. They provide physical training which accords with child instincts, and keep the child out of mischief and often out of jail. Here, as elsewhere, the suppression by civilized and urban life of the instinct for play and amusement is responsible for much of what we call "crime" and "depravity." In school children should not only be surrounded by hygienic environment, but should be taught the value of hygiene. The suggestion of an annual "health day" or "health week" may prove a fruitful one for this purpose.

SEC. 5. *Voluntary and business organizations.*—Societies to prevent the spread of tuberculosis, social diseases, insanity, etc., or to advocate labor or health legislation (state and national), are now numerous and active. It is being found that philanthropy and profit are not always antagonistic. Labor organizations are connecting the health movement with the eight-hour movement. Farsighted employers are providing social secretaries to watch over the health, comfort, and happiness of their employees, and are often eager for practical suggestions in these matters.

Corporations that have installed apparatus for ventilation and sanitation, even sometimes for the benefit of their machinery rather than their employees, have in known instances gotten back the cost in lessened illness and greater efficiency of work.

An interesting experiment near Paris was that of a mill employing 44 men and 75 women and children. Largely through the services, instruction, and suggestions of a medical officer there was not a single death in three years.

The temperance reform has to-day a powerful impulse in the demands by employers for more efficient labor and by the public for greater safety in travel. Locomotive engineers, conductors, and ship captains who drink can not get employment.

Life-insurance companies may possibly in the future realize their opportunity to make financial gains by participation in the health movement.

Finally, one of the greatest potential agencies for bringing about health reform is the public press. It is already interested and active in the movement, although the good it does is often undone by inserting quack advertising. This not only does direct harm, but often ties the hands of the editor, preventing him from expressing any disapproval of nostrums, however injurious or immoral.

SUMMARY OF CHAPTER IX—CONSERVATION THROUGH PERSONAL HYGIENE.

SECTION 1. *Its importance.*—Personal hygiene is not only of direct importance to the individual, but furnishes the public opinion from which, and from which alone, sound public and semipublic hygiene can spring. Public hygiene will be ineffective unless supported by personal hygiene. The milk and water supply of a city may be ideal as supplied at a dwelling, but may be carelessly contaminated there. Observation shows that many of the world's most vital men and women have practiced hygiene and often thereby turned weak constitutions into strong ones. Cornaro, the Venetian nobleman, about to die at 37, adopted the "temperate life," taking especial care not to overeat. He lived to be nearly, or quite, 100.

SEC. 2. *Branches of personal hygiene.*—Personal hygiene comprises hygiene of environment (air, soil, dwellings, clothing), hygiene of nutrition, and hygiene of activity. The ideal conditions of health require purity in air, purity and proper use of food, and a proper balance between mental and physical activity, rest, and sleep. The present world-wide interest in personal hygiene and physical education is not due to any startling discoveries, but to the rediscovery of the importance of truths long insisted upon by the medical profession.

SEC. 3. *The hygiene of environment.*—The prime factor in environment is the atmosphere. Originally man was doubtless an outdoor animal. Civilization has brought him an indoor environment, and with it tuberculosis. Experiments in hospitals have shown that the agitation of the air by dry sweeping greatly increases bacteria. Air in a confined room may be contaminated by chemicals contained in wall paper, plaster, or mortar. The one place in which the individual has most control over his air supply is the bedroom. The fashion now of sleeping with wide-open windows, or even out-of-doors, is certain to improve American vitality. The windows of living and work rooms also may be open even in winter if a window board is used to deflect the air upward and prevent a cold stratum forming on the floor. The outdoor life or the abundant use of fresh air is an almost certain preventive of colds. This fact was commented upon by Franklin over a century ago, and has been rediscovered many times since, especially in the experience of army troops. The evils of bad air are not confined to its chemical content. A room is sometimes "close" simply because it is hot or overmoist or devoid of any air current.

The effect of air on the skin and of radiation of heat from the body is important. Consequently, a proper use of air involves a proper use of clothing, which needs to be both porous and light.

Closely connected with air hygiene is the hygiene of light. "Where sun and air enter seldom the physician enters often." The lighting of dwellings and schoolrooms is especially important with reference to the eyes. This is true also of even the color and texture of the printed page we read. Probably one-fourth of all educated people in America suffer from disturbances due more or less to eye strain and its numerous indirect effects.

SEC. 4. *The hygiene of nutrition.*—The scientific study of diet has only just begun, and few authoritative results can yet be stated. That diet has a distinct relation to endurance has been rendered probable by many investigations, which seem to show in particular that avoidance of overeating, and especially of excess in protein, and thorough mastication are wholesome rules. In the choice of foods the individual must be given a wide latitude. His own instinct, restored and educated by avoiding food-bolting which blunts it, will probably be a truer guide than the wisest of physiologists. Diseased foods, such as oysters polluted with sewage, may transmit typhoid and other maladies.

SEC. 5. *Drug habits.*—Poisons, whether taken into the body or produced within, are injurious. The commonest form of intoxication is alcoholic. Its evils are becoming more apparent than ever before. As Metchnikoff says, it lowers the resistance of the white corpuscles, which are the natural defenders of the body. It predisposes to tuberculosis and numerous other diseases. The findings of the "Committee of Fifty" for the investigation of the liquor problem are important evidence of the evils of the use of alcohol, and these have not received the attention which they deserve. Absinthe in France is being recognized now as a distinct menace to the nation, and in Germany there is a tendency toward a lessened use of alcohol in all its forms. But the movement against the abuse of alcohol has reached its highest point in America.

The evils of tobacco are less and are less appreciated. Its stunting effects on the growing child are especially harmful.

SEC. 6. *Activity hygiene.*—It is an encouraging sign of the times that baths are coming more into vogue, both through the private bath tub for the wealthy and the public baths for the poor. During the last generation the importance of exercise has come to be acknowledged, due largely to the growth of modern athletics. The athletic ideal of the Greeks was, however, higher than that which now prevails in this country. Overexertiou, physical and mental, is one of the chief American faults. The danger signal of fatigue is seldom observed, and the instinct for recreation and amusement is often stifled.

Sec. 7. *Sex hygiene.*—Undue reticence on this subject is responsible for the general ignorauce as to the extent to which the abuse of the sex relation is injuring this aud every nation, physically, mentally, and morally. Syphilis poisons the blood and affects all parts of the body. It makes the individual a "bad risk" for life insurance companies for several years, and is likely to be transmitted to others through a kiss or through the use of a common towel, while the danger of transmitting from husband to wife, or vice versa, continues for many years. Syphilis is one of the few really hereditary diseases, and the saddest of all facts couuected with it is that the guilty parent may escape and the innocent children suffer. Gonorrhœa, while usually cured without apparent impairment of health, destroys fertility, and for years after it has apparently ceased may be rearoused. It is responsible for a large number of the cases of infantile blindness and for a larger percentage of many of the serious troubles of women. The social diseases, while seldom assigned as a cause of death, are known to predispose to other diseases and greatly to shorten life.

Sec. 8. *Personal hygiene in general.*—The cumulative effect of hygiene, or of lack of hygiene, needs emphasis. Breathing, eating, working, and sleeping are matters of daily habit. If they are wrong, the evil, however slight, being repeated every day for many years, produces cumulative effects more subtle, but often more powerful, than the effects of sudden infection or accident.

SUMMARY OF CHAPTER X—ARE HYGIENIC MEASURES EUGENIC?

Section 1. *The prolongation of weak lives.*—The question has been raised whether reduction in infant and child mortality will not weaken rather thau strengthen the race by interfering with natural selection and favoring the survival of the unfit. It is pointed out that the mortality at later ages of life has not decreased, as has that in the earlier ages. There is probably, however, a sufficient explauation of this in the fact that the improvement in hygienic living has not as yet affected adults as much as children. Parents are quick to apply for the benefit of their children new methods of preventing disease, such as sterilizing milk, but do not take the same precautions for themselves. The hurry and stress of modern life has in fact tended to produce in some respects more unhygienic habits among adults than prevailed under the simpler conditions of a generation ago.

Sec. 2. *Children's diseases impair both fit and unfit.*—It must be borne in mind also that the same children's diseases and other causes which tend to kill the unfit child also tend to injure the proper development of the fit. Consequently a lessening of children's diseases will have the effect of not only prolonging weak lives, but also of prolonging and developing the strong. Statistics, so far as available, appear to show that where iufant mortality is the highest, mortality at all ages is high.

Sec. 3. *Fitness is relative to environment.*—What is sometimes called degeneration does not deserve that name. A lessening of physical strength, for instance, can not be called degeneration if conditions under civilization do not require the same physical strength as our barbarian ancestors needed. It is adaptatiou to existing conditions which measures fitness.

Whatever danger of degeneration there may be from the care of the insane and defective classes can be avoided if the health ideals of the nation are strong and broad enough to meet the situation, for with these high health ideals will come a demand which will prevent the perpetuation of the unfit and through the mere force of public opinion lead in general to healthier marriages.

Summary of Part IV.—*Results of conserving life.*

SUMMARY OF CHAPTER XI—PROLONGATION OF LIFE.

Section 1. *Life is lengthening.*—So far as we can judge from statistics of the average duration of life, it has been on the increase for three hundred and fifty years, and is now increasing more rapidly thau ever before. During the seventeenth and eighteeuth centuries the increase was at the rate of about four years per century; during the first three-quarters of the nineteenth century the rate was about nine years. At present in Massachusetts life is lengthening at the rate of about fourteen years per century; in Europe about seventeen; and in Prussia, the land of medical discovery and its application, twenty-seven. In India, where medical progress is practically unknown, the life span is short (twenty-five) and remains stationary.

SEC. 2. *Table showing further practicable prolongation.*—It is possible to estimate the effect on the length of life of the partial elimination of various diseases. Using the statistics, experience, and estimate of 18 physicians as to the preventability of each of the list of 90 causes of death, we find that the length of life could easily be increased from forty-five to sixty, an increase of one-third, or fifteen years. This would result in a permanent reduction in death rate of about 25 per cent. The principal reductions would be from infantile diarrhea and enteritis, over 60 per cent of which could be prevented, with the result of an addition to the average length of life of 2.32 years. Bronchopneumonia, also an infant disease, could be prevented to the extent of 50 per cent, whereby life would be lengthened by 0.60 year. Meningitis, which is usually fatal at the age of two, could be preveuted by at least 70 per cent, and this preveution would leugthen the average life by 0.60 year. Eighty-five per cent of death by typhoid fever is unnecessary, and if avoided would lengthen life at least 0.65 year. It would be feasible to prevent at least 75 per cent of cases of tuberculosis of the lungs, and thereby to lengtheu life by about two years. If the deaths from violence were reduced ouly 35 per cent, human life would be increased by 0.86 year. The prevention of 45 per cent of cases of pneumonia would lengthen life by 0.94 year. These seven diseases alone could easily be reduced by these amounts so as to lengthen life by eight years. This could be done simply through insistence by the public on pure milk, pure water, pure air, and reasonable protection from accidents.

SEC. 3. *Diagram showing effect of prolongation at different ages.*—If we take the diagram representing the life table of Massachusetts for 1893–1897, we may use it as the basis for constructing an ideal curve to show the effect of prevention if applied according to the ratios of prevention given in the preceding table. The results agree substantially with those found in the table and show that about thirteen or more years could easily be added to the average duration of life. The diagram also shows the extent to which the additional life would fall iu different ages. The per cent of life which would fall to the ages between 17½ and 60, taken as the working period, would remain the same, namely, about 55 per cent.

SEC. 4. *Fifteen years a safe minimum estimate of prolongation possible.*—The estimate of fifteen years is a minimum because, first, it takes no account of future medical discoveries, such as a method of curing or preventing cancer and of postponing old age, as would Metchnikoff; second, it takes little account of the cumulative influence of hygieue. The full beuefit of hygieue can not be felt until it is practiced throughout life, and not at the approach of specific danger. Most so-called "causes" of death are merely the last straws which break the camel's back. When a pure water supply prevents deaths from typhoid fever, it prevents two or three times as many deaths from other causes. Third, it takes no account of the racial effects of new health ideals leading, in a geueral way, as they must, to healthier marriages.

SEC. 5. *Need of lengthening human life.*—With increase of knowledge the period of education or preparation for life must constantly increase. This fact creates a need for a longer life, with the later periods of life increased in proportion. The result of such a prolongation will be not the keeping alive of invalids, but the creation of a population containing a large number of vigorous old men. Metchnikoff says, "The old man will uo longer be subject to loss of memory or to intellectual weakness; he will be able to apply his great experience to the most complicated and most delicate parts of the social life."

SEC. 6. *The normal lifetime.*—It is usually recognized that human life is abnormally short, but no exact determination has ever been made of what constitutes a normal lifetime. Flourens maintains that a mammal lives five times the length of its growing period, which would mean, since the growing period for man does not cease until about 30, a normal human lifetime of one hundred and fifty years. Another method of estimating normal life is to reckon the length of normal life as the time when old age now sets in, 83 years. But clearly, if Metchnikoff is right in thinking that old age itself is abnormal, the normal lifetime must exceed 83. Many remarkable cases of longevity are on record, but most cases of reputed centenarians are not authenticated. Drakenburg's record was authentic, and he lived to be 146. Mrs. Wood, of

Portland, Oreg., recently died at 120. To what extent these exceptional cases could be made common can not, as yet, be known.

SUMMARY OF CHAPTER XII—THE MONEY VALUE OF INCREASED VITALITY.

SECTION 1. *Money appraisal of preventable wastes.*—Doctor Farr has estimated the net economic value of an English agricultural laborer at various times of life by discounting his chance of future earnings after subtracting the cost of maintenance. On the basis of this table we may construct a rough estimate of the worth of an average American life at various ages, assuming that only three-fourths of those of working age are actually earners of money or housekeepers. It gradually rises from a value of $90 in the first year to $4,200 at the age of 30, and then declines until it becomes negative for the higher ages. This estimate assumes $700 per year as the average earnings in middle life. This is largely conjecture, but is regarded as a very safe estimate. Applying this table to the existing population at various ages in the United States, we find that the average value of a person now living in the United States is $2,900, and the average value of the lives now sacrified by preventable deaths is $1,700. The latter is smaller than the former because the age of the dying is greater than the age of the living. Applying the $2,900 to the population of eighty-five and a half millions, we find that our population may be valued as assets at more than $250,000,000,000; and since the number of preventable deaths is estimated at 630,000, the annual waste from preventable deaths is 630,000 times $1,700, or about $1,000,000,000. This represents the annual preventable loss of potential earnings.

We saw in Chapter III that there are always 3,000,000 persons in the United States on the sick list, of whom about 1,000,000 are in the working period of life and about three-quarters are actually workers and must lose at least $700, which makes the aggregate loss from illness more than $500,000,000. Adding to this another $500,000,000 as the expense of medicines, medical attendance, special foods, etc., we find the total cost of illness to be about $1,000,000,000 per year, of which it is assumed that at least one-half is preventable. Adding the preventable loss from death, $1,000,000,000, to the preveutable loss from illness, $500,000,000, we find one and a half billions as the very lowest at which we can estimate the preventable loss from disease and death in this country. The true figures from the statistics available may well amount to several times this figure, but when statistics are based partially on conjecture, they need to be stated with special caution.

SEC. 2. *The cost of conservation.*—In Huddersfield the annual deaths of infants for ten years had been 310. By systematic education of mothers, the number in 1907 was reduced to 212. The cost of saving these 98 lives was about $2,000, or about $20 each. Gen. Leonard Wood declared that the discovery of the means of preventing yellow fever saves annually more lives than were lost in the Cuban war. The hook-worm disease in the South impairs the earning power of its workmen by 25 or 50 per cent. To restore this earning power costs, by curing this disease, on an average, less than $1 for each case. These and other examples show that the return on investments in health are often several thousand per cent per annum. Probably no such unexploited opportunity for rich returns exists in any other field of investment. An actuary suggests that if insurance companies should combine to contribute $200,000 a year for the purpose of improving the public health, the cost would be one-eighth of 1 per cent of the premiums, and it would be reasonable to expect a decrease in death claims of much more than 1 per cent. Even this 1 per cent would make a profit of more than seven times the expense.

SUMMARY OF CHAPTER XIII—THE GENERAL VALUE OF INCREASED VITALITY.

SECTION 1.—*Disease, poverty, and crime.*—Money estimates of waste of life are necessarily imperfect and sometimes misleading. The real wastes can only be expressed in terms of human misery. Poverty and disease are twin evils and each plays into the hands of the other. From each springs vice and crime. Again, whatever diminishes poverty tends to improve health, and vice versa.

SEC. 2. *Conservation of natural resources.*—The conservation of our natural resources—land, raw materials, forests, and water—will provide the food, clothing, shelter, and other means of maintaining healthy life, while the conservation of health likewise tends in many ways to conserve and increase wealth. The more vigorous and long-lived the race, the better utilization it v make of its natural resources. This will be true for two reasons in particul First, the greater inventiveness or resourcefulness of vigorous minds in vigor bodies. Civilization consists chiefly in invention and the most progressive nati are those whose rate of invention is most rapid. Second, the greater foresi and solicitude for the future. As it is usually the normal healthy man v provides life insurance for his family, so it will be the normal healthy nat whch will take due care of its resources for the benefit of generations unborn.

SUMMARY OF CHAPTER XIV—THINGS WHICH NEED-TO BE DONE.

SECTION 1. *Enumeration of principal measures.*—Federal, state, and munici boards of health should be better appreciated and supported. Their powers investigation, administration, and disseminating information should be larged. School hygiene should be practiced, and personal hygiene more emp sized. The multiplication of degenerates should be made impossible.

INTRODUCTION.

At the conclusion of his White House address on the "Conservation of Natural Resources," President Roosevelt said:

> Finally, let us remember that the conservation of our natural resources, though the gravest problem of to-day, is yet but part of another and greater problem to which this nation is not yet awake, but to which it will awake in time, and with which it must hereafter grapple if it is to live—the problem of national efficiency.

The conditions on which national efficiency depend may be classified under three heads: Those relating to physical environment, those relating to social environment, and those relating to human nature. Under the first head comes the problem of the conservation of land, forests, minerals, and water. The second comprises social questions, whether political, economic, or religious. The third covers the study of the characteristics of man himself—physical, mental, and moral.

This report falls under the third head, concerning as it does vitality, the measure of life itself, and the basis of all human qualities. The object is to review briefly the condition of American vitality, contrasted with the vitality of other nations; to show the extent to which it may be increased; and to point out the value of such an increase in years of life, enjoyment of life, and economic earnings.

The world is gradually awakening to the fact of its own improvability. Political economy is no longer the "dismal science," teaching that starvation wages are inevitable from the Malthusian growth of population, but is now seriously and hopefully grappling with the problem of abolition of poverty. In like manner hygiene, the youngest of the biological studies, has repudiated the outworn doctrine that mortality is fatality, and must exact a regular and inevitable sacrifice at its present rate year after year. Instead of this fatalistic creed we now have the assurance of Pasteur that "It is within the power of man to rid himself of every parasitic disease," as well as the optimistic writings of Metchnikoff and others.

Many evidences of a world-wide awakening to the importance of improving human vitality can be given. Among them are the recent English parliamentary report of the interdepartmental committee on physical degeneration (prompted by the fact that the English army recruits were decreasing in stature); in America, the many societies and congresses to prevent and control tuberculosis, insanity, alcoholism, social diseases and vice, and infant mortality; the growth of preventive sanatoria, dispensaries, and similar institutions; the establishment of numerous journals of preventive medicine, both technical and popular; the increased attention to the subject of health in the public press; the spread of athletics and the physical training movement; the growth of the custom among city people to organize country clubs, and the increasing popularity of golf and similar recreations; the constant agitation and legislation in reference to child labor, slaughterhouses, impure foods, milk supply, and water contamination; the increased vigilance of health boards; the growth of sick-benefit associations and insurance among working men; the efforts toward improving the sanitary surroundings and hours of labor of workmen, and especially of women and children, and, finally, the movement to secure a national organization of health at Washington.

A number of universities are supporting special investigations in physiology, hygiene, and preventive medicine. Some schools also have placed the allied subjects of domestic science and dietetics on their curricula, while physical education is receiving constantly increasing attention. Within a generation every important college, school, and branch of the Young Men's Christian Association has come to have a gymnasium and classes in gymnastics. Research institutions are being established, such as the Rockefeller Institute for Medical Research, the fund established by Mrs. Sage to study diseases of old age, and the Memorial Institute for Infectious Diseases. The home-economics movement is rapidly growing and seems destined to improve greatly the management of American homes.

The practice of medicine, which for ages has been known as the "healing art," is undergoing a gradual but radical revolution. The change is based on the conviction that an ounce of prevention is worth a pound of cure. As teachers and writers on hygiene, as trainers for athletes, as advisers for the welfare departments of large industrial plants, and in many other directions, physicians are finding fields for practicing preventive medicine. There is a still higher stage of medical science than that of fighting or preventing disease in the individual—the stage which has been called "biological engineering," i. e., the study of the conditions under which the individual may reach his highest efficiency. In the development of this science physicians are turning from private practice to public service and are acting as health officers in federal, state, and city governments, as heads of sanatoria and as medical inspectors of schools, factories, mines, and shops. Even the family physician is in some cases being asked by his patients to keep them well instead of curing them after they have fallen sick.

Finally, we have also the suggestion by Sir Francis Galton of the new science of eugenics, which seeks to study the hereditary conditions of human vitality. He has established a research fellowship on the subject at the University of London. Already Karl Pearson and others have made valuable contributions to the study of human degeneration, the effect of tuberculosis on the race, the comparative number of offspring of various classes, and the extent to which mating is "assortative," so that like marries like.

With all these facts in view it requires no great prophetic vision to see that among the rising generation there will be a great movement to conserve human life and health. The power and success of this movement will depend upon the realization of its stupendous importance. A chief object of this report is, in a conservative and cautious manner, to help make this importance clear.

Part I.—THE LENGTH OF LIFE VERSUS MORTALITY.

CHAPTER I.—*The length of life.*

SECTION 1.—*In different places.*

By those who have never considered the problem, death and disease are accepted as a matter of course. In individual cases it is recognized that a death or an illness might have been prevented, but the idea that the death rate could be changed in any appreciable degree, or controlled, is quite foreign to the mind of the average man. Charles Babbage wrote: "There are few things less subject to fluctuaton than the average duration of life of a multitude of individuals." [a]

If this statement were correct, we should find the average duration of life [b] and the death rate substantially the same in different places and at different times. The facts do not conform to this view. Modern life tables show that the average length of life in the leading countries of the world varies remarkably, as the following figures will illustrate.[c]

Modern duration of life.

Country.	Males.	Females.
Sweden, 1891–1900	50.9	53.6
Denmark, 1895–1900	50.2	53.2
France, 1898–1903	45.7	49.1
England and Wales, 1891–1900	44.1	47.7
United States (Massachusetts, 1893–1897) [a]	44.1	46.6
Italy, 1899–1902	42.8	43.1
Prussia, 1891–1900	41.0	44.5
India, 1901 [b]	23.0	24.0

[a] Samuel W. Abbott, M. D.: "Vital Statistics of Massachusetts for 1897," Thirtieth Annual Report of the State Board of Health of Massachusetts, 1898.

[b] Statistiques Generale de la France: Statistiques Internationales, etc., 1907, p. 566. See also J. A. Baines, "The Peradventures of an Indian Life Table," Journal Royal Statistical Society, 1908, Vol. LXXI, part 2, p. 310, where the average duration of life for males is given as 23.6.

When we consider that the average duration of life in India is scarcely more than one-half that of France and less than one-half

[a] Charles Babbage: A Comparative View of the Various Institutions for the Assurance of Lives, p. 15. London, 1826.

[b] By average duration of life or the life span is meant the average length of life among a large number of persons born taken at random. It is not the same as the average age at death in a community during a year, since that community may contain an abnormally large proportion of infants, or of any other "age group."

[c] Some of the figures, especially those for India, rest on imperfect data, but they are believed to be sufficiently accurate for general comparison.

that of Sweden, we must conclude that the length of human life is dependent on definite conditions and can be increased or diminished by a modification of those conditions.

SECTION 2.—*At different times.*

Striking corroboration of this conclusion is found as soon as we compare the average duration of life at different periods of time. The earliest attempt to discover a law of human mortality appears to be that of Ulpian, a Roman pretorian prefect, about 220 A. D. The meaning of his table is somewhat doubtful, but it is assumed to refer to "expectation of life," which for ages up to 20 is given as thirty years.[a]

This estimate is so crude and vague as to be of little value for comparative purposes. Professor Finkelnburg, of Bonn, estimates that—

> The average length of human life in the sixteenth century was only between eighteen and twenty years, and that at the close of the eighteenth century it was a little over thirty years, while to-day it is between thirty-eight and forty years.[b]

In Geneva the records go back over three centuries showing the following life span:[c]

16th century	21.2
17th century	25.7
18th century	33.6
1801–1883	39.7

Here we see an increase in the span of life of 100 per cent in three or four centuries. The last few decades, moreover, tell a striking story of increase. It is one of the boasts of the nineteenth century that the splendid medical and scientific advances of that period have aided in a distinct lengthening of life.

In 1693 the British Government borrowed money by selling annuities, and in 1790, a century later, it did the same thing. While the first venture proved satisfactory, the second caused a great loss to the Government, owing to the improvement in longevity which had taken place, and which was estimated, for the annuitant class, at 20 years.[d]

If we compare Ogle's English life tables for 1871–1881 with those of Farr for 1838–1854, we find an increase in life span of 1.4 years for males and 2.8 for females.[e]

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[a] See Irving Fisher: Mortality Statistics of the United States Census, Publications of the American Economic Association, Monograph on Federal Census, 1899, p. 157. Taken from Assurance Magazine, VI, p. 314; note.

[b] George M. Kober, M. D.: "Conservation of Life and Health by Improved Water Supply," publications of conference on the conservation of natural resources, 1908, p. 23. Washington, D. C., privately published. From Finkelnburgs' "Organisation der öffentl. Gesundheitsphlage in der Kulturstaaten" in Handbuch der Hygiene, 1893.

[c] From Mallet in "Annales d' Hygiene," XVII, 169; quoted by Dr. Edward Jarvis, "Political Economy of Health," in Fifth Annual Report, Mass. Board of Health, 1874.

[d] See Dr. Southward Smith, Transactions British Social Science Association, 1857, p. 498, quoted by Dr. Edward Jarvis, ibid.

[e] R. Mayo-Smith; Statistics and Sociology, p. 178. New York (Macmillan), 1895.

A still greater improvement has been effected since Ogle's figures of 1871–1881:

Lifetime in England and Wales:	
Males—	
1838–1854	39.9
1891–1900	44.1
Females—	
1838–1854	41.8
1891–1900	47.8

Similar improvements are observable in other countries.

Lifetime in France:	
Males—	
1817–1831	38.3
1898–1903	45.7
Females—	
1817–1831	40.8
1898–1903	49.1
Lifetime in Prussia:	
Males—	
1867–1877	35.3
1891–1900	41.1
Females—	
1867–1877	37.9
1891–1900	44.6
Lifetime in Denmark:	
Males—	
1835–1844	42.6
1895–1900	50.2
Females—	
1835–1844	44.7
1895–1900	53.2
Lifetime in Sweden:	
Males—	
1816–1840	39.5
1891–1900	50.9
Females—	
1816–1840	43.5
1891–1900	53.6

It is difficult to obtain American life tables that go far enough back into history to display increases in the life span similar to those just presented; yet comparisons of Abbott's Massachusetts life tables for 1893–1897 with Elliott's Massachusetts tables for 1855 and Wigglesworth's Massachusetts and New Hampshire life tables of a century ago give us a progressive increase from 35 in 1789 [a] to 40 in 1855 [b] and 45 in 1893–1897.[c] Unfortunately no tables exist for the United States as a whole from which similar comparisons might be made. Good and reliable vital statistics are among our most crying needs. Meech's life tables, based on the census figures of 1830, 1840, 1850, and 1860, showed a life span for the whole country of 42.[d]

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[a] E. Wigglesworth: "Table showing the probability of the duration, the decrement and the expectation of life in the States of Massachusetts and New Hampshire, formed from 62 bills of mortality on the files of the American Academy of Arts and Sciences in the year 1789." Memoir of the American Academy of Arts and Sciences, Vol. II, p. 133.

[b] Proceedings American Association for the Advancement of Science, 1857, pp. 61 and 69.

[c] Abbott, loc. cit.

[d] Levi W. Meech: System and Tables of Life Insurance, ed. of 1886, pp. 255–259. The figures for life span at different periods given in this paragraph have been secured by averaging the figures for males and females.

The census of 1880 gave some 70 sets of life tables for different registration States and cities. The expectation of life for white males was given for Massachusetts as 44, New Jersey 46, District of Columbia 41, and New York City 33, but in constructing the tables "the census was too prodigal as to quantity and somewhat careless as to quality. It is difficult to separate the wheat from the chaff. The table should have been accompanied by a running criticism. The general defect was that no attempt was made to correct the deficiencies in the returns for infants."[a] The census for 1890 gives only a few life tables, and that for 1900 none.

In striking contrast to these recent increases of the life span in progressive countries is the table for backward India, which showed no advance in twenty years.[b]

Lifetime in India:

Males—	
1881	23.7
1901	23.6

Chapter II.—*The mortality rate.*

Section 1.—*Relation of longevity and mortality.*

The average duration of life and the death rate[c] are two complementary magnitudes. An increase in the life span means a decrease in the death rate, and vice versa; in fact, in a "stationary" population (a population in which the annual number of deaths equals the annual number of births, and without emigration or immigration), it will be true that the average duration of life and the death rate are mathematically the "reciprocals" of each other.[d] Thus, if the death rate is 20 deaths per annum for each 1,000 of population (i. e., twenty one-thousandths per annum), the average duration of life would be $\frac{1000}{20} = 50$ years.

If this reciprocal relation between duration of life and mortality held true in every population, it would be easy to translate death rates into average duration of life, and conversely; but unfortunately such a simple calculation is impracticable under conditions existing in America, and even in most countries of Europe. With the exception of France, few countries have even approximately an equality between deaths and births and an absence of emigration and immigration. In America, where the deaths are exceeded by the births, and where there is a large immigration of young men and women in the prime of life, the death rate is smaller than it would be if our population were "stationary." The annual death rate in the United

[a] Fisher: Mortality Statistics of the United States Census, American Economic Association Monograph on the Federal Census, 1899, p. 160.

[b] Baines: "The Peradventures of an Indian Life Table," Journal of the Royal Statistical Society, 1908, Vol. LXXL, pt. 2, p. 310.

[c] A death rate is the ratio of the number of deaths during a year to the population, taken at some point in the year, usually the middle.

[d] For a short explanation of this reciprocal relation, which is more fully explained in works on actuarial science, see Fisher: Mortality Statistics of the United States Census, pp. 149–150. It is interesting to see the graphic interpretation of this reciprocal relation by means of the diagram in Chapter XI of this Report.

States is probably about 18 per thousand[a] of population. The reciprocal of this would be 1,000÷18, or 55 years, which is altogether too high an estimate for the average length of life in the United States.

It is possible to "correct" the death rate for "age distribution" so that its reciprocal will be the true average duration of life, but the calculation is a difficult and tedious one. We are forced, therefore, to get along in most cases with the "crude death rate," or the quotient of the number of deaths in a year divided by the population. This figure is much easier to obtain than a corrected death rate or its reciprocal, the average duration of life.

Our data for death rates are far more voluminous than our data for the average duration of life. Although theoretically death rates are not an unerring indication of longevity, they furnish in practice very valuable information. In a general way death rates may be compared with each other, especially in the same community. For instance, a decrease in the death rate in New York City from one year to another is practically a certain indication of improvement in vital conditions.

SECTION 2.—*Mortality in various regions.*

Forty years ago the variations in the death rates of the different sections of Europe were given by Quetelet[b] as follows:

Death rate per 1,000 population.

Northern Europe	24.3
Central Europe	24.5
Southern Europe	29.7

To-day the death rates of various countries compare with each other as in the following table:

Modern death rates per 1,000 of population.[c]

Denmark (1906)	13.5
Sweden (1906)	14.4
England and Wales (1906)	15.4
United States (registration area) (1907)	16.5
Germany (1905)	19.8
France (1906)	19.9
Italy (1906)	20.8
Japan (1905)	21.9
India (males,[d] 1901)	42.3

As we found in the study of duration of life, so we find here wide variations from country to country. Italy presents a death rate larger by nearly one-sixth than that of the United States, while famine-tortured and plague-ridden India's mortality rate is twice that of France and three times the rates of Denmark and of Sweden.

[a] W. F. Willcox: "Death Rate of the United States in 1900," publications of the American Statistical Association, Vol. X, p. 155.

[b] Quetelet, Physique Sociale, Vol. I, p. 281. These figures refer to the experience of different periods between 1801 and 1831.

[c] With the exception of the figures for India, this table is taken from figures furnished by the Bureau of the Census.

[d] Baines, loc. cit., p. 310.

Even the fairly homogeneous population of our registration States in America shows variations in death rates.[a]

Death rate per 1,000 population in 1900.

Michigan	13.9
Vermont	17.0
Massachusetts	17.7
New York	17.9

The death rate in Michigan, at the one extreme, is thus but three-fourths that of New York at the other extreme. This difference may probably be accounted for in part by the difference in the age constitution, as the population for Michigan contains a larger proportion of population in young and vigorous life than does New York.

SECTION 3.—*Urban and rural mortality.*

Comparison of urban and rural death rates also gives us variations.[b]

Death rates per 1,000 population in 1900.

Massachusetts:	
Urban	17.9
Rural	17.1
Michigan:	
Urban	15.3
Rural	13.3
New Jersey:	
Urban	18.8
Rural	15.5

Interesting comparisons may be made of the death rates of American cities varying in size and location. The death rate per 1,000 of population in 1906 was given[c] as 14.2 (probably incorrect) in Chicago, in Boston 18.9, in New York 18.6, and in Philadelphia 19.3. Cleveland, Ohio, was credited with a death rate of but 16, while Cincinnati, in the same State, had 20.8. The causes of such differences are not always attributable to variations in size. New Haven, for instance, a larger Connecticut city than either Hartford or New London, had a lower death rate in 1900 by 2.2 and 2.5, respectively, per 1,000 population. The differences are accounted for partly by differences in age constitution, partly—it is unfortunately true—by differences in the accuracy of the collected statistics, partly by differences in size and location, and partly by differences in the vigilance of the public and private health authorities.

European cities show even greater variations in mortality than these just given for the United States.

[a] Twelfth Census of the United States, Vol. III, p. LVIII.
[b] United States Census Bulletin, No. 83, 1901.
[c] Seventh Annual Census Report on Mortality Statistics, 1906.

Death rates of European cities per 1,000 population, 1897.[a]

Locality.	High.	Locality.	Low.
Dublin	39.9	Frankfort on the Main	15.6
Moscow	36.9	The Hague	16.2
Belfast	31.3	Berlin	17
St. Petersburg	31	Amsterdam	17.8

[a] One must doubt, however, the accuracy of some of these figures, especially the Russian. The rates in Moscow and St. Petersburg in 1906 are reported as 25.8 and 25.5, respectively, which do not comport with the rates for 1897.

SECTION 4.—*Race and condition.*

The variations in death rates among different races are well known. The black race, for example, always suffers a higher mortality than the white. In Boston during the half century from 1725 to 1774 the death rate per 1,000 is given as ranging from 56 to 87 for the blacks and only from 30 to 41 for the whites. Thus the maximum white death rate was lower than the minimum black death rate.[a]

In 1906 the death rate per 1,000 in all registration cities having not less than 10 per cent colored inhabitants was 17.2 for whites and 28.1 for blacks.

These racial differences may be ascribed in part to different habits and conditions of life, but probably in part also to varying racial susceptibility to disease.

The relation of social status to the rate of mortality has been often discussed and offers a partial explanation of racial or national variation of death rate. That a well-to-do class, properly fed and clothed and with opportunity for leisure, will be less susceptible to disease and death than a poverty-stricken class, ill-fed and overworked, has been repeatedly shown by statistics. Newsholme has stated,[b] for example, that in Glasgow the death rate among tenants of large houses is much lower than among the tenants of smaller dwellings:

	One and two room houses.	Three and four room houses.	Five rooms and over.
Death rate per 1,000 occupants in 1885	27.7	19.5	11.2

In Paris comparison has been made between two quarters known to be rich, on the one hand, and, on the other, a third quarter known to be poor.

Death rate per 1,000 population.[c]

Rich quarters:	
Elysee	13.4
Opera	16.2
Poor quarter:	
Menilmontant	31.3

[a] Lemuel Shattuck, "The Vital Statistics of Boston," p. xiii. Reprinted in "Bills of Mortality, 1810–1849," city of Boston, 1893.

[b] Arthur Newsholme, "Vital Statistics," London (Swan Sonnenschein), 1899, p. 163.

[c] E. Levasseur, "La Population Francaise," Paris, 1891, Vol. II, p. 403.

In Russia a similar comparison has been made between peasants who own no land, those who own less than 13½ acres, those who own between 13½ and 40½ acres, and so on up the scale of proprietorship.[a]

Peasant death rate per 1,000, Government of Voronezh, 1889–1891.

Class of household.	Per 1,000.
Having no land	34.7
Having less than 13.5 acres	32.7
Having 13.5 and less than 40.5 acres	30.1
Having 40.5 and less than 67.5 acres	25.4
Having 67.5 and less than 135 acres	23.1
Having more than 135 acres	19.2

Occupational comparisons are often made; and while they must be handled with great care, especially because of differences in age, the following may be said to display roughly the variations in death rate among social classes.

Death rate of males per 1,000, according to occupations, for registration States, 1900.[b]

Mercantile and trading	12.1
Clerical and official	13.5
Professional	15.3
Laboring and servant	20.2

Special industries have high death rates from special diseases. Among dusty trades, for instance, tuberculosis is very common.[c]

Finally, the experience of industrial life-insurance companies, which deal largely with the poorer classes of society, shows a higher death rate than that displayed by the experience tables of other insurance companies.[d]

Insurance mortality per 1,000.

Age	Ordinary insurance, English experience.	Industrial insurance, Metropolitan Life.
20	7.3	10.5
25	7.8	14.1
35	9.3	17.2
55	21.7	35.2
70	64.9	91.0

We find also great variations in death rates dependent on varying climatic or seasonal conditions, on the prevalence or absence of certain pests, on the fluctuating virulence of specific diseases, and on numerous natural differences. Other significant factors in mortality are historical events, such as wars, plagues, and epidemics. Hard times bring increased mortality, whether due to natural or politico-economic causes. There remain to be mentioned also deaths by accident in all its many forms.

[a] I. M. Rubinow, "Poverty's Death Rate," publications of the American Statistical Association, December, 1905, p. 348.

[b] "Twelfth Census of the United States," Vol. III, p. cclxi.

[c] See Frederick L. Hoffman, "Mortality from Consumption in dusty trades," Bulletin No. 79 of the U. S. Bureau of Labor.

[d] Haley Fiske, "Industrial Insurance," The Charities Review, March 1898, p. 33.

SECTION 5—*Mortality historically.*

Not only does the death rate vary greatly from place to place and from one social class to another, but it changes in a most marked fashion from period to period in history. The records of old cities show that a decided decrease in mortality has been steadily going on. In London, for example, the rate per 1,000 has fallen from 50 in 1660–1679 to 15 in 1905, a decrease of 70 per cent. In the plague years, 1593, 1625, 1636, and 1665, the death rates per 1,000 were 240, 310, 130, and 430.[a] The "black death" in 1348–9 probably swept away half of the population in many localities throughout Europe.[b]

Mortality in London.[a]

Year.	Rate per 1,000.
1660–1679	50
1680–1728 [b]	80
1729–1780	40
1905	15.1

[a] Kober, *loc. cit.*, p. 25.
[b] These years include the period of pests.

Within a quarter century London has cut her death rate in half, while Vienna, if we may trust the figures, has within a century reduced her rate from 60 per 1,000 of population to 23.[c] Similarly, the mortality rate in Boston has been lowered from an estimated 34 per 1,000 [d] in 1700 to 19 to-day.

Mr. John K. Gore, actuary of the Prudential Insurance Company, shows [e] that the average death rates per 1,000 of population among typical American cities was, for the white population, as follows:

Years.	Death rate per 1,000.
1804–1825	24.6
1826–1850	25.7
1851–1863	28.3
1864–1875	25.4
1876–1888	22.9
1889–1901	21.0

The record even of the last thirty years displays a fall in death rates that may inspire us with buoyant hope for the future. The mortality rate per 1,000 has fallen in Berlin from 33 in 1875 to 16 in 1904; in Munich, from 41 in 1871 to 18 in 1906; and in Washington, from 28 in 1875 to 19 in 1907.[f]

Between 1890 and 1906 New York lowered her death rate per 1,000 from 25.4 to 18.6, and Boston from 23.4 to 18.9. The mortality rate in the whole registration area of the United States fell from 19.6 per 1,000 in 1890 to 16.1 in 1906, although the area in the last-named year included a larger proportion of urban population.

[a] See Farr, Vital Statistics, London, 1885, p. 131.
[b] See Abbot Gasquet, "The Black Death of 1348 and 1349," London (Bell), 1893.
[c] A. F. Weber, "The Growth of Cities," New York, 1899, pp. 355, 356.
[d] Shattuck, *loc. cit.*, pp. xii-xiv.
[e] "On the Improvement in Longevity in the United States during the Nineteenth Century."
[f] Kober, *loc. cit.*, p. 25.

We have also vital records for the city of Habana, running back over a century. These show that while the death rate in 1802 was given as 54.6 per 1,000, rising in cholera years even as high as 103.4 (1833) and in the last year of Weyler's concentration methods as high as 91, the rate during the eight years from 1899–1906 ranged from 20.4 to 33.6.[a]

These records also show the remarkable and sudden fall that may be brought about by a change in the living conditions of a community. During the three "concentration" years of 1896, 1897, and 1898 the mortality rate per 1,000 was 51.7, 78.7, and 91, respectively. In 1899, the first complete year of American occupation, the rate dropped to 33.6, and since then it has ranged between 20.4 and 24.4. There can be no question that the improvement was almost wholly due to the sanitary reforms introduced by Colonel Gorgas, and the other United States Army surgeons under Gen. Leonard Wood.

The record of American Army sanitarians in the Panama Canal Zone shows as striking results as in Cuba. The death rate in Panama during 1887, when the French canal companies held occupation, ran over 100 per 1,000. In 1906 the death rate was 49 per 1,000, while in 1907 it fell to less than 34. Colonel Gorgas attributes the decrease in the general death rate in great part to improved sanitation, though he adds that "increased wages, better food, and better clothing have no doubt played a considerable part in the general improvement of the health."[b]

SECTION 6.—*Adult and infant mortality.*

Mortality varies greatly with age. The improvement in the city death rate of the past half century has been especially marked among the young.

It is true that in countries of the same degree of civilization the infant death rate is remarkably constant,[c] but this is probably accounted for by the similarity in the methods of feeding of infants. Certainly where there is a difference in conditions there will be found a difference in mortality. Thus, the comparison between the mortality of infants fed on cow's milk and those fed on mother's milk shows that the former is five to ten times that of the latter.[d]

Although the infant mortality rate is probably falling,[e] the decrease is not accompanied by a lowering of the mortality of later life. There is an increased mortality beyond the age of 50 years. In Massachusetts the death rates by age changed during thirty years as follows:

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[a] "Report of the National Sanitary Department of the Republic of Cuba," Habana, 1906, p. 78.

[b] Letter from Col. W. C. Gorgas, chief sanitary officer, Canal Zone.

[c] See E. B. Phelps, "A Statistical Study of Infant Mortality," quarterly publication of the American Statistical Association, September, 1908. Mr. Phelps shows the utter unreliability of most statistics of infants under 1 year of age, especially in the United States.

[d] See Harald Westergaard, "Mortalität und Morbilität," Jena, 1901, p. 364.

[e] Edward E. Graham, M. D., "Journal of the American Medical Association," September 26, 1908; also "British Medical Journal," February 1, 1908, p. 271.

Death rate in Massachusetts per 1,000 of population in each age period.[a]

Age.	1865.	1895.
5-9	9.6	6.2
10-14	5.1	3.2
15-19	9.6	5.3
20-29	12.6	7.1
30-39	11.7	9.7
40-49	12	13
50-59	17	20
60-69	33	39
70-79	70	82
80 and upward	168	185

[a] "Vital Statistics of Massachusetts," 1856-1895, p. 755.

Here, while the death rate for all age periods under 40 has materially decreased, the later periods of life have suffered progressive increases in mortality rate.[a]

As Frederick L. Hoffman has expressed it:

There is, of course, no question whatever that the American death rate, using the term in a very comprehensive sense, has substantially declined within the last fifty years, but it is equally evident that this decline has been at the younger ages, aud not during the period of life which, economically, is of the greatest value. There is no doubt that the mortality of adult ages is still decidedly excessive.

The same tendency, viewed from the standpoint of the expectation of life,[b] is disclosed in the study of two Massachusetts life tables, compiled nearly a century apart—one, Wigglesworth's life tables for Massachusetts and New Hampshire in 1789, though not very accurate; the other, Abbott's Massachusetts life tables for 1893-1897.

Expectation of life in Massachusetts.

Age.	1789.	1897.	Age.	1789.	1897.
0	35.5	45.4	60	15.4	15.1
10	43.2	50	80	5.9	6.1
20	34.2	42	90	3.7	3.4
40	26	28.2			

These figures indicate that the expectation of life at the earlier ages is much greater than a century ago, but that for the age of 60 and upward it has remained practically stationary.

[a] At first sight it would seem that this increased mortality in later ages could be explained away as due to the larger uumber of persons who are saved from earlier death and tend to produce a higher mortality at the older ages. I speak of this because very intelligent persons have drawn this conclusion. But it is obviously fallacious, since the figures do not indicate the *number* of deaths in different periods, but the death *rates* in different periods of life per 1,000 at each period. There are, to be sure, as a consequence of saving lives in the past, more old meu now living than otherwise there would be, and there will be more deaths, but the figures show that these old deaths have increased faster than the number of old men. This fact raises the suspicion, therefore, that the lives which have been saved by the hygiene of a generation ago are weak lives. Whether this is a tenable hypothesis or not will be discussed in Chapter X.

[b] "Expectation of life" at any given age is the mean after-lifetime of persons who reach that age. Thus 100 persons have an expectation of life of 50 at the age of 10, if the total life to be lived by those 100 persons before death is five thousaud years.

English life tables[a] for three decades ending 1900 display the same tendency.

English life tables—Expectation of life.

MALES.

Age.	1871–1880.	1881–1890.	1891–1900.
0	41.4	43.7	44.1
20	39.4	40.3	41
60	13.1	12.9	12.9
80	4.8	4.5	4.6

FEMALES.

Age.	1871–1880.	1881–1890.	1891–1900.
0	44.6	47.2	47.8
20	41.7	42.4	43.4
60	14.2	14.1	14.1
80	5.2	5	5.1

These tables show that there is improvement at the younger ages for the period 1891–1900 over the period 1871–1880. For ages over 60 there has been a retrogression. It is observable, however, that between the periods 1881–1890 and 1891–1900 the figures for 60 years have remained stationary, and for 80 have slightly improved.

In other words, a baby to-day has in prospect a much longer average lifetime than did the baby of two generations ago; but a man or woman 60 years old has in prospect an average after lifetime no greater than formerly.

The proximate cause of this contrast would seem to lie in the fact that the mortality from many of the diseases of later life has been and is on the increase. The death rates from diabetes, heart disease, and Bright's disease have all doubled in thirty years.[b]

Cancer is probably on the increase,[c] and "to-day one in every 21 men who have reached the age of 35 and one in every 12 women who have reached 35 eventually die of that disease."[d]

In addition, there may be mentioned other diseases, arteriosclerosis, nephritis, apoplexy, paresis, disorders of the liver, and all manner of degeneration, all of them maladies of adult life, and all of them apparently tending to increase.

SECTION 7.—*Particular diseases.*

We turn now to the ravages made by particular diseases in the modern world. The death rate in the United States from tuberculosis of all forms equals the combined death rate from smallpox, typhoid fever, diphtheria, cancer, diabetes, appendicitis, and meningitis.

[a] "Supplement to Sixty-fifth Annual Report Register-General of England and Wales," pt. 1, 1907, p. XLVIII–LI.

[b] Norman E. Ditman, M. D., "Education and its Economic Value in the Field of Preventive Medicine," Columbia University Quarterly, Supplement to June, 1908, p. 38.

[c] Elie Metchnikoff, "The Nature of Man," English translation, New York (Putnam), 1903, pp. 213, 214; see also "United States Census mortality statistics, 1906," p. 29.

[d] Ditman, loc. cit., p. 38.

The death rate from tuberculosis of all kinds in the registration area was 183.6 per 100,000 in 1907.[a] The rate is high among negroes.[b] Large as these figures are, they represent a considerable decrease since 1900.[c] Tubeculosis is a preventable disease.

On a par with tuberculosis in the number of its victims in this country stands pneumonia.

The mortality statistics of the last census show that in the registration area of the United States pneumonia is responsible for 11 per cent of all deaths. Pneumonia is now known to be a communicable disease, the germ of which is very widely distributed; but there is great need for special researches into the modes of spreading this formidable disease. In the meantime the best protection is to "keep in condition." While the germ of pneumonia is the exciting cause of the disease, predisposing causes are acute or chronic alcoholism, exposure to cold, extreme exhaustion, and debility of any kind.

Typhoid fever is in some places yielding to preventive measures in a most striking manner. The fall in the death rate from typhoid in the registration area from 46.3 per 100,000 of population in 1890 to 33.9 in 1900,[d] and to 32.1 in 1906,[e] may be safely ascribed to improvements in the water and milk supplies of our cities. The surprising reduction of the typhoid-fever death rate in individual cities, resulting from definite improvements in the water supply, gives direct confirmation of this statement.

The typhoid mortality in Munich during 1856 was 291 per 100,000 of population. The city at that time contained numerous cesspools, and the water supply was largely obtained from wells and pumps. From 1856 to 1887 there was great activity in the filling up of cesspools, the abandonment of pumps and wells, and the installation of modern sewers. A pure water supply was also secured, the water being brought from a distance. The typhoid-fever death rate fell in 1887 to 10 per 100,000 of population—a reduction of 97 per cent.[f]

In Hamburg the typhoid mortality for 1880–1892 ranged from 24 to 88, averaging 39.7 per 100,000. In May, 1893, a filtration plant was opened, and the rate fell in that same year to 18. For the five years following it averaged only 7.2, showing a reduction of over 80 per cent.[g]

The introduction of a water filter in the town of Lawrence, Mass., in 1893 was followed by a reduction in deaths caused by typhoid from 105 in 1892 to 22 in 1896, one-fifth the previous figure. Filter-

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[a] For a careful statistical study of tuberculosis see "Tuberculosis in the United States," United States Census, issued for the International Cougress on Tuberculosis, 1908. See also "Bulstrode's Report in Thirty-fifth Annual Report of (English) Local Government Board, 1905–6," and Arthur Newsholme, M. D., "Prevention of Tuberculosis," 1908.

[b] For the prevalence of tuberculosis in the negro, see F. L. Hoffman's valuable monograph, "The American Negro," publications of the American Economic Association, August, 1896.

[c] This decrease is shown by the exact figures (not estimated) in the registration area.

[d] Twelfth Census of the United States, Vol. III, p. cxliv.

[e] Mortality Statistics, U. S. Census Office, 1906, p. 30.

[f] Ditman, loc. cit., p. 17.

[g] A. C. Abbott, M. D., "The Hygiene of Transmissible Diseases," Philadelphia, Saunders, 1899, pp. 88–89.

ing the city water in several other American cities has shown abrupt declines in the typhoid death rate almost as remarkable.[a]

Another method of pointing out the importance of a pure water supply is to compare the mortality rates from typhoid fever of cities that secure water from various sources of supply, as the following table shows:[b]

Death rate from typhoid fever per 100,000 of population, 1902–1906.

4 cities using ground water from large wells	18.1
18 cities using impounded and conserved rivers or streams	18.5
8 cities using water from small lakes	19.3
7 cities using water from Great Lakes	32.8
5 cities using surface and underground water	45.7
19 cities using polluted river water	61.1

Thus far our studies indicate that typhoid fever will cease to be a "problem" in any community having clean water and an uninfected milk supply, and in which cases of the disease are treated as dangerous and contagious."[c]

Unfortunately such communities are too rare at present.

Perhaps the most common and neglected source of danger of infection from typhoid is the ordinary house fly or, as Dr. L. O. Howard, chief of U. S. Bureau of Entomology, would have us call it, the "typhoid fly."

Smallpox, another disease that yields readily to preventive measures, has decreased greatly in virulence and mortality since the introduction of vaccination. In Prussia, for example, the death rate from smallpox per 100,000 population was 24.4 in the period from 1846–1870. In 1874 vaccination, which up to that time had been only intermittently utilized, was made compulsory, and the death rate per 100,000 fell at once to 1.5 for the years 1875–1886.[d]

Other European States, however, have been more lax than Germany. In 1886 the death rate from smallpox in Switzerland was fifty-fourfold that of Germany; in Belgium, forty-eightfold; in Austria, eighty-onefold, and in Hungary, six hundred and sevenfold.[e]

Babbage[f] states that "it has been shown by M. Duvillard that the introduction of vaccination has increased the mean duration of human life about three years and a half." Before Jenner's utilization of vaccination to guard against smallpox that disease was causing one-tenth[g] of all deaths of the human race, just as does tuberculosis to-day, while "nearly twice as many were permanently disfigured by its ravages. In England 300 per 100,000 population died annually from it. It is computed that during the eighteenth century 50,000,000 people died of smallpox in Europe."[h]

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[a] See Kober, loc. cit., pp. 18, 19.

[b] Kober, loc. cit., p. 15.

[c] M. J. Rosenau, L. L. Lumsden, and Jos. H. Kastle, "The origin and prevalence of typhoid fever in the District of Columbia," Hygienic Laboratory Bulletin No. 44, 1908, p. 9.

[d] Ditman, loc. cit., p. 8.

[e] Floyd M. Crandall, "A century of vaccination," American Medicine, December 7, 1901.

[f] Loc. cit., p. 8.

[g] Crandall, loc. cit., p. 6.

[h] Ditman, loc. cit., pp. 6, 52–3.

Boston was visited twelve times by smallpox epidemics in the century and a half ending 1800.[a]

Yet where vaccination has been made compulsory, or where it is generally resorted to, smallpox has virtually disappeared. The last census reported but 3,500 deaths from smallpox in the United States in 1900. Even as long ago as 1826 Denmark was enforcing the practice of vaccination so vigorously that not a single case had appeared for eleven years.[b] Habana, during the eight years prior to the American intervention, reported 3,132 deaths from smallpox. In 1899, the year following the American entry, there were four deaths, and three more during the next seven years—a virtual uprooting of the disease.[c]

The present outcry against vaccination is based on a misunderstanding, and is one of many evidences of the imperative necessity of the diffusion of correct knowledge among the people on matters of hygiene and preventive medicine. Whether vaccination should be made compulsory is a fair question, but that it is efficacious is not open to question. The argument that because some unvaccinated persons escape during an epidemic all would escape is too absurd to deserve serious consideration.[d]

Yellow fever first appeared in serious form at Philadelphia in 1793, when one-tenth of that city's population died of it in the space of six and a half weeks. Since 1793 the United States has had 500,000 cases, resulting, it is estimated, in about 100,000 deaths. In 1900 it was discovered that a species of mosquito is responsible for the transmission of this fever, and in consequence of this knowledge and its application the disease is now practically banished from this country.[e]

The marked decrease in the death rate from yellow fever in Habana since the American intervention in 1898 is shown in the following table. The deaths from yellow fever numbered 4,420 in the eight years from 1891 to 1898, while in the eight years from 1899 to 1906 they numbered but 465.

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[a] Shattuck, loc. cit., p. xiv.

[b] Crandall, op. cit.

[c] Report of National Sanitary Department of the Republic of Cuba, Habana, 1906, p. 79.

[d] For the most scientific statistical studies of vaccination see W. R. Macdonnell, Biometrika, Vol. I, 1902, p. 375, and Vol. II, 1903, p. 135. J. Brownlee, Biometrika, Vol. IV, 1905–6, p. 313. F. M. Turner, Biometrika, Vol. IV, p. 483. Karl Pearson, Biometrika, Vol. IV, and Philosophical Transactions of the Royal Society of London, Series A, Vol. 195, p. 43. Humphreys, Journal of the Royal Statistical Society, 1897, p. 503. For the best of antivaccination literature see Alfred Russell Wallace, "The Vaccination Delusion," and Milnes, Journal Royal Statistical Society, 1897, p. 552 (Comment by G. U. Yale, p. 608). For both sides see Report of the Royal Commission on Vaccination, 1897.

[e] Ditman, loc. cit., pp. 11–12.

Yellow-fever death rate in Habana, 1870–1906.

[Rate per 100,000 population.[a]]

Before American intervention.		After American intervention.	
1870	300.5	1898	67.8
1880	324.5	1899	42.5
1890	153.6	1900	124.0
1895	275.8	1901	6.9
1896	639.5	1902	0
1897	428	1903	0
		1904	0
		1905	8.0
		1906	4.3

[a] Report of the National Sanitary Department of the Republic of Cuba, 1906, p. 79.

These results have been due partly to the elimination of the contagion-carrying mosquito and partly to the general improvement of the city's sanitary appointments.

A similar contrast might be drawn between the death rates from yellow fever at Panama during the efforts of the French to dig the canal and during the American work under the sanitary regulations of Colonel Gorgas. If the same thoroughgoing measures used in Habana and at Panama were employed among our own people, the resultant blessings would be almost equally striking.

The impressive figures just presented, showing the fall in mortality from so many of the most dangerous diseases, point clearly to the value of preventive measures in the conflict with disease. The fall in tuberculosis mortality is directly due to the growing use of hospitals, which have tended to isolate[a] consumptives, and to a use of our recently acquired knowledge of the efficacy of fresh air and the outdoor life; typhoid fever has virtually disappeared when water and milk supplies have been made pure, the open privy abolished, and flies and other carriers of the specific cause of the disease have been provided against; smallpox has given way before vaccination; yellow fever is fast disappearing now that the agent of transmission is known; while many of the less serious diseases are losing their power, purely owing to preventive methods.

Some diseases, once the scourges of humanity, have practically disappeared from the civilized world.

Scurvy up to the latter half of the eighteenth century decimated the armies and fleets of Europe and afterwards proved a menace to the civilized population. During Anson's famous expedition about the year 1750, 600 out of 900 died, chiefly from scurvy. The use of lime juice and fresh vegetables has practically eradicated the disease.[b]

"Cholera was wont to visit the cities of the Atlantic coast in the past about every ten years, and it was a standing menace to the world every summer. It was not uncommon for the disease to decimate whole towns and cities. Since the discovery of its cause, however, it has been robbed of its terrors, and the children of to-day will probably never know of it except by name."

Malaria has been on the decrease ever since the discovery that the malarial organism is transported by a species of mosquito. Even the

[a] See Arthur Newsholme, "The phthisic death rate," Journal of Hygiene, July, 1906.

[b] Ditman, loc. cit., 14–15.

five years ending 1906 show a progressive decline in the death rate from malarial fever in the registration area. The figures are 5.4, 4.3, 4.2, 3.9, and 3.5 deaths per 100,000 of population, for the five years in question. In themselves, the figures are so small as to show the virtual disappearance of the disease, at least from the Northern States. It is still very common in the Southern States. Its evil is by no means to be measured by the deaths it causes. It produces chronic disability and predisposes to other diseases.[a]

Finally, the furnishing of pure milk to the infant population of the cities is eliminating year by year the infant scourges—diarrheal diseases and related maladies.

There are of course diseases which show no sign as yet of decreasing. The census volume, "Mortality Statistics of 1906" (p. 29) gives only one important disease (diabetes) as actually on the increase within the registration area, but several which are given as having "fluctuating rates," such as cancer, heart disease, and Bright's disease, seem still to have an upward trend.

It is known that malaria is preventable. Why, then, is it not prevented in the South? Probably for two reasons. First, the facts are not generally known, owing to lack of vital statistics in the Southern States. Second, owing largely to this ignorance no adequate effort has yet been made. As an example of what can be done we have the cleaning of Habana by Colonel Gorgas. The following table, supplied by him, shows the deaths from malaria from 1899 to 1907:

Year.	Number of deaths.	Year.	Number of deaths.
1899	909	1904	44
1900	325	1905	32
1901	151	1906	26
1902	77	1907	[a] 23
1903	51		

[a] Annual Report of the Sanitary Department for the City of Habana for the year 1907.

"The first year quoted, 1899, the malarial deaths were excessive, owing to the crowding into the city of the 'reconcentrados' and the starvation and misery thereby involved.

The next year, 1900, was about the normal rate. The next year, 1901, begins to show the effect of the antimalarial work done in connection with the yellow-fever work; 1901 was the first year of mosquito work in Habana. The last year, 1907, shows only 23 deaths from malaria. This means practically the extinction of malaria in Habana. The item of 23 deaths in 1907 from malaria would probably be covered by the malarial cases coming in from the rural districts and by mistakes in diagnosis."

The preventability of accidents is beginning to be appreciated. It is now proposed by Mr. W. H. Tolman to establish in New York a museum of safety and sanitation to demonstrate this fact. Mr. Frederick L. Hoffman, statistican of the Prudential Insurance Company, estimates the number of deaths among male workers alone in 1908 as between 30,000 and 35,000.[b]

[a] See "Report to the Conservation Commission" of L. O. Howard. "Economic loss to the people of the United States through insects that carry disease."

[b] "Industrial accidents," Bulletin of the Bureau of Labor, 1908.

Part II.—THE BREADTH OF LIFE VERSUS INVALIDITY.

Chapter III.—*Prevalence of serious illness.*

Section 1—*Loss of time.*

Length of life is but one indication of vitality. Everyone recognizes that the life of a valetudinarian or an invalid, however long, is but a narrow stream. We may therefore conceive, besides the dimension of length, another dimension of life which may be called its "breadth." By the breadth of life we mean its healthiness. Just as length of life is limited by and opposed to mortality or death, so breadth of life is limited by and opposed to invalidity or illness.

An ideally healthy life, free throughout from ailment and disability, is rarely if ever found. But it is the aim of hygiene to approximate such an ideal. Some persons imagine that length of life can be purchased only at the expense of breadth, and counsel the deliberate shortening of one's life for the sake of living it faster. In exceptional cases such a policy may be justified, but the study of longevity reveals the fact that, as a rule, length and breadth of life are not opposed, but that, on the contrary, the one can seldom be increased without an increase of the other. Centenarians are usually persons who have been exceptionally free from illness[a] and who have performed a large amount of work. This work is usually physical labor out of doors, although the few mental workers completing the century have also lived busy lives.

Chevreul, the distinguished French chemist who died twenty years ago at the age of 103, lived a life of great activity and usefulness as laboratory experimenter, as industrial chemist, as university professor, and as a writer and lecturer. It was said of Alexander Von Humboldt, who was 90 at the time of his death, that he had not only lived twice as long as others in years, but that in work accomplished he had lived twice as much per day, thus enjoying four times the average lifetime.

It is shortsighted to spend more vitality each day than we earn. Such a policy must not only prove suicidal sooner or later, but tends to narrow one's life in every way long before the arrival of death. The ordinary individual burns the candle at both ends. The result is an almost universal invalidism in some degree. While statistics are lacking, a wide observation seems to justify the conclusion that it is difficult to find a man or woman over 40 whose health has not become impaired in some manner. Few who have not studied the facts realize how common illness is, although we all know it is sufficiently common to make the question "How are you?" the ordinary form of salutation.

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[a] Metchnikoff, "The Prolongation of Life," English translation, New York, (Putnam's) 1908, p. 145.

Serious illness is such as totally incapacitates a person from work, whether or not he is confined to his bed. The burden of serious illness is felt in several distinct ways. There is the annual idleness entailed by this illness, the cost of maintaining institutions devoted to the care of the sick, and the cost to the individual of medicines, medical service, and nursing.

The amount of invalidity or illness in a community has been estimated by a number of different investigators, and in a number of different ways. While the results vary somewhat, on the whole they harmonize fairly well.[a]

The most careful consideration of the various illness statistics available was made by Farr. He finds that the rate of invalidity increases with age, and at the later ages increases with great rapidity. The material he has used has come chiefly from various friendly societies in Great Britain and Scotland, and especially from the East India Company. His final conclusion is probably nearly as valid to-day as then. It is that corresponding to each death in a community, there are a little more than two years of illness.

Another way of expressing the same fact is that for each annual death, there are on the average two persons constantly sick during the year. Applying this estimate to the United States,[b] in which about 1,500,000 persons die per annum, there are probably at all times about 3,000,000 persons seriously ill. This means an average of thirteen days per annum for each inhabitant.[c]

Returns gathered from 79 benefit societies in Scotland, aggregating over 100,000 members, and based on the experience of various periods between 1750 and 1821, showed that the average duration of sickness for each member under seventy years of age was ten days per year, 2 of which were assumed to be "bedfast" days, five as days of walking sickness, and three as days of permanent sickness.[d]

SECTION 2—*Particular diseases.*

It has been estimated that the number of persons in the United States constantly suffering from tuberculosis reaches 500,000. Of this number probably about half are totally incapacitated, while the remainder are able to earn about half of the ordinary wages.[e]

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[a] See Farr, Vital Statistics, London, 1885, pp. 501–514. Harald Westergaard, Mortalität und Morbilität, Jena, 1901, p. 683. See also a pamphlet by Hiram J. Messenger, actuary of the Travelers' Insurance Company, Hartford "The Rate of Sickness;" Pettenkofer, quoted by Uffelman, Handbuch der Hygiene, p. 3. Edwin Chadwick, "The Health of Nations," ed. by B. W. Richardson, 2 vols. (Longmans), London, 1887, Vol. I, p. 57; Mayo-Smith, "Statistics and Sociology," New York, (Macmillan) 1895, p. 158; "Statistische Jahrbuch für das Deutschen Reich, 1908," pp. 304–305.

[b] Judging from the experience of sickness insurance, there is more sickness in the United States than in England. See Dr. Edward Jarvis, "Political Economy of Health," Fifth Report of Mass. Board of Health, 1874. Dr. Jarvis also points out that estimates of illness are based on experience of provident persons among whom illness is a minimum, and that the estimates of illness take no account of chronic ailments or "decreptitude."

[c] Farr, Vital Statistics, p. 513.

[d] Edwin Chadwick, "The Health of Nations," vol. 1, pp. 56–57.

[e] Irving Fisher, "The Cost of Tuberculosis in the United States and Its Reduction," paper read before International Congress on Tuberculosis, Washington, 1908; see also Huber, "Consumption and Civilization," Philadelphia, 1906; and Bardswell, "The Consumptive Workingman," London, 1906.

For every death from typhoid fever, there are about 8 cases of illness, averaging seventy-five days of incapacity. But this is not the only loss. Professor Sedgwick has said, "Hazen's theorem asserts that for every death from typhoid fever avoided by the purification of a polluted public water supply two or three deaths are avoided from other causes. Working under my direction Mr. Scott MacNutt has recently been able to confirm this surprising theorem, and even to establish it as conservative. We have also gone further than Hazen and discovered what the other causes are from which deaths are thus avoided; and, although our results are not yet all published, I may say that conspicuous among these are pneumonia, pulmonary tuberculosis, bronchitis, and infant mortality."[a]

The prevalence of the hook-worm disease in the South has been a matter of investigation for several years by Doctor Stiles[b] of the Public Health and Marine-Hospital Service. The disease is remarkable not so much for its fatality, though that is large, as for the chronic incapacity for work which it produces. For this reason the hook worm has been nicknamed the "germ of laziness." The disease extends over the whole South, and is responsible for a large part both of the sickness (the so-called "laziness") and of the poverty of the "white trash."

There are no satisfactory statistics as to the extent of hook-worm disease; but it has been estimated that the sufferers are incapacitated for labor from one-fourth to one-half of their time. Most striking is the fact that the disease is easily preventable through the introduction of sanitary measures as well as curable by the proper (drug) treatment of the present victims. It has been largely eradicated from Porto Rico.[c] Hook-worm disease weakens when it does not kill and is known to be a precursor of tuberculosis.

Malaria is one of the diseases which are fatal relatively seldom, but which shorten life by predisposing to other causes of death, and narrow life by reducing working efficiency by a large percentage. Doctor Howard states that each year there are probably 3,000,000 cases of malaria in the United States, most of which are in the South. This is practically all preventable.[d]

Dr. Prince A. Morrow says that the number of syphilitics in the United States has been estimated at 2,000,000. This disease is not only in itself a danger, but it also causes a large number of diseases of the circulatory and nervous systems.

Doctor Morrow says that the extermination of social diseases would probably mean the elimination of at least one-half of our institutions for defectives. The loss of citizens to the State from the sterilizing influence of gonorrhea upon the productive energy of the family, and the blighting destructive effect of syphilis upon the offspring are enormous. In the opinion of very competent judges social

[a] W. T. Sedgwick, "The Call to Public Health," Science, 1908, p. 198.

[b] Report upon the Prevalence and Geographic Distribution of Hook-worm Disease in the United States," Hygienic Laboratory, Bulletin No. 10, February, 1903, Washington.

[c] "Reports of Commission on the Suppression of Uncinariasis, 1904, 1905, 1906–7, 1907–8, San Juan, P. R." This commission has been succeeded by a bureau, the "Anemia dispensary service."

[d] See L. O. Howard, Report to Conservation Commission, "Economic loss to the people of the United States through insects that carry disease."

disease constitutes the most powerful of all factors in the degeneration and depopulation of the world.

Among the troops stationed in the Philippines, the venereal morbidity during the year 1904 was 297 per 1,000, largely exceeding the morbidity from malarial fevers and diarrhea; 22 out of every 1,000 soldiers were constantly ineffective from venereal diseases, four times as many as from any other disease.

The statistics of the Navy Department show during the same year, that venereal disease was chargeable with a percentage of 25.2 of the total number of sick days in the hospital from all causes combined. In four years 949 men were discharged from the navy for disability from venereal disease. The statistics of the English army show that among the troops stationed in India 537 per 1,000 were admitted to the hospital for venereal disease. Of the troops returning home to England after completing their time of service in India, 25 per cent were found to be infected with syphilis.

No statistics exist for venereal disease in civil life. It may be more prevalent than in the army and navy service, since the inhibitory influence of military restraint and discipline do not exist and the opportunities for licentious relations are more abundant.

Neisser, a distinguished German authority, states that "fully 75 per cent of the adult male population contract gonorrhea and 15 per cent have syphilis."

What syphilis and gonorrhea represent in the lowered working efficiency of our population—to say nothing of the still more important subject of increased mortality—is impossible to estimate; but it would be difficult to overemphasize the grave danger to national efficiency from these and the other venereal diseases. And here again the most striking point is that the venereal diseases are preventable.

Alcoholism and drug addiction are maladies of frightful prevalence. They are so familiar as to be taken by many as a matter of course.

Venereal diseases and inebriety, whether alcoholic or drug, frequently lead to insanity. Statistics are not yet able to prove conclusively that insanity is increasing, though this is the opinion of the best judges.[a]

Dr. C. L. Dana, formerly president of the New York Academy of Medicine, believes the increase in insanity to be real as well as apparent. He says: "The annual increment of insane in Massachusetts, according to the Massachusetts board of lunacy, is 400 in about 10,000, or 4 per cent." At this ratio the annual increment for the United States would be approximately 5,600. "We may say that in the last twenty-five years the ratio of insane to sane has shown an apparent gradual increase from 1 to 450 to 1 to 300, and this latter seems to be about the ratio in those communities of North America and Europe in which modern conditions of civilization prevail. This average has varied but little in the last few years; the slight yearly increase probably will not change rapidly and probably not continue, for when the increase in the insane reaches a certain point of excess society will have to take notice of it and correct it."[b] There are no accurate fig-

[a] For a critical examination of statistical data on insanity, see Humphreys, (Noel, A.), "The alleged increase of insanity," Journal of the Royal Statistical Society, June, 1907.

[b] "Psychiatry in its Relation to Other Sciences," section on psychiatry at the International Congress of Arts and Sciences, St. Louis, September, 1904.

ures of the number of insane. Mr. Sanborn estimates that the number exceeds 250,000 in the United States.

Among defective and disabled classes are to be especially mentioned the feeble-minded, paralytic, crippled, blind, and deaf mutes. The aggregate disability of these groups is greater than is commonly recognized. The preventability is still less appreciated.

With reference to the losses each year from industrial accidents: The statistical report of the Interstate Commerce Commission for the year ending June 30, 1907, shows that during that year 11,800 persons were killed and 111,000 injured on our American railways, these figures including passengers, employees, and all other persons. A large number of the victims were railway employees, for whose safety Congress has passed a number of laws. The total number of cases of industrial accidents can not be estimated, owing to the lack of statistical information; but Census Bulletin 83 gives the number of deaths by accident and violence in 1900 at 57,500.

"Of 29,000,000 workers in the United States over 500,000 are yearly killed or crippled as a direct result of the occupations in which they are engaged—more than were slain and wounded throughout the whole Russo-Japanese war. More than one-half this tremendous sacrifice of life is needless."[a]

Mr. Frederick L. Hoffman estimates[b] that the number of accidents among men employed in the United States in 1906 was 208,000, of which about 5,000 were fatal. These figures are exclusive of mining, railway, and shipping accidents.

John Mitchell[c] estimates that for every 100,000 tons of coal produced in the United States one mine worker is killed and several injured. In 1907 the figures were 2,500 coal miners killed and 6,000 seriously injured.

In Wisconsin from October 1, 1906, to October 1, 1907, the total number of accidents reported which incapacitated the victim by at least two weeks was 13,572. The accidents to employees constituted 53 per cent of this number.[d]

Special trades have special perils for workmen. "Among diseases to which workmen are most often subject are the so-called 'inanition, scrofula, rachitis, pulmonary consumption, dropsy;' also rheumatic troubles, pleurisy, typhoid fever, gangrene, and the various skin diseases. Every epidemic, be it typhoid, smallpox, scarlet fever, dysentery, cholera, etc., draws its greatest army of victims from this class. For every death that occurs among the richer and higher classes there are many in the working class. It is the workman engaged in unhealthy factories first of all who fills the hospitals and their death chambers."[e]

It is the pollution of the air breathed by workmen, whether the pollution come through poisons or through dust, that makes many trades dangerous. Among poisonous trades are the many lead-using

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[a] Ditman, loc. cit., 43.

[b] In an article contributed to the "New Encyclopedia of Social Reform," 1908.

[c] Speech before the Governor's Conference on Conservation, White House, May, 1908.

[d] Thirteenth biennial Report, Bureau of Labor and Industrial Statistics, Madison, Wis., 1908.

[e] C. F. W. Doehring, "Factory Sanitation and Labor Protection," Bulletin Department of Labor No. 44, January, 1903, p. 2.

industries, foundries, and chemical factories. Investigations of the dust-producing trades have been made, showing the results on the respiratory systems.

Hirt's statistics show that men employed in dust-producing occupations suffer much more frequently from pneumonia and consumption than do those not exposed to dust. The relative frequency of these diseases per 100 workmen is as follows:

Cases of consumption and pneumonia per 100 workers in certain occupations.

	Consumption.	Pneumonia.
Workers in metallic dust	28	17.4
Workers in mineral dust	25.2	5.9
Workers in mixed dust	22.6	6.0
Workers in animal dust	20.8	7.7
Workers in vegetable dust	13.3	9.4
Workers in nondusty trades	11.1	[a] 4.6

[a] George M. Kober, M. D., "Industrial Hygiene," Bulletin of Bureau of Labor, March, 1908, p. 477.

Mr. Owen R. Lovejoy, secretary of the national child-labor committee, has condensed a table from Indiana reports [a] showing the high injury rate suffered by children in the industries.

Injuries to children in Indiana, 1907.

Proportion of adults injured	5 per 1,000 3 per 1,000
Proportion of children injured	20 per 1,000 10 per 1,000

The injury rate for children is shown to be three to four times as great as for adults.

Chapter IV.—*Prevalence of minor ailments.*

Section 1.—*Importance of minor ailments.*

The statistics of morbidity which we have given refer to forms which are relatively acute; but there are many milder forms which do not incapacitate the patient from work or compel him to take to his bed. The extent of these milder ills is not generally appreciated. They are often carefully guarded secrets. The individual often knows only his own physical troubles, but is unaware of the fact that almost every person about him has such troubles also. Once you penetrate beneath conventional acquaintance there will almost invariably be found some functional impairment of heart, liver, kidneys or bladder; or dyspepsia, gastritis, jaundice, gallstones, constipation, diarrhea; or insomnia, neurasthenia, nervousness, neuritis, neuralgia, sick headache; or tonsilitis, bronchitis, hay fever, catarrh, grip, colds, sore throat; or rupture, hernia, phlebitis, skin eruption; or rheumatism, lumbago, gout, obesity; or decayed teeth, baldness, deafness, eye ailment, spinal curvature, lameness, broken bones, dislocations, sprains, bruises, cuts, burns, or other "troubles."

[a] "Eleventh Annual Report of the Department of Inspection of Indiana, 1907," Exhibit C, pp. 166–198.

These so-called "minor ailments" will undoubtedly in the next few years receive much more attention than now. Until recently the physician has been accustomed to treat only acute diseases, but as preventive medicine gradually replaces curative medicine the physician will be more called upon to treat minor ailments. These are generally the first warnings of more serious troubles. If what seem to be "mere colds" were less commonly neglected, tuberculosis would more often be caught in its incipiency, and pneumonia and diphtheria would often be prevented.

From the "common colds" also tonsilitis and abscess of the ear can and do come, purulent inflammations of the pneumatic and venous cavities of the face and skull, and meningitis and cerebral abscess—all of which destroy many lives annually; or the lives may be saved by a surgical operation after a serious and prolonged illness. Tonsilitis, in turn, in addition to lighting up furious inflammations in its own immediate vicinity, can be held responsible in a certain number of cases for serious diseases at a distance from its own site. These are septic arthritis (inflammation of joints), septic peritonitis, appendicitis, endocarditis (valvular disease of the heart)—severe and frequently fatal diseases. Gastritis or gastroenteritis, sick headache, jaundice, lumbago, are not usually of serious import, but sometimes are the signs that point to an underlying cause (alcoholism, overeating, chronic protein intoxication, worry—business or domestic—sedentary life, etc.) which will lead later to arteriosclerosis, chronic nephritis, toxic amblyopia (optic nerve blindness), cirrhosis of the liver, cerebral hemorrhage or valvular disease of the heart.[a]

If the first twinges of rheumatic pains were heeded, gout and the dreaded arthritis deformans would lose most of their terrors. We could then arrest a great majority of serious affections at the very gateway. It can hardly be doubted that even such diseases as cancer, whose causation is not yet understood, gain a foothold through lowered vital resistance, manifesting itself at the first in minor ailments of some kind.

The American neurasthenia, widespread and subtle, has its grip on thousands of men and women, driving them from home and offices annually to sanitaria or various health resorts, and so breaking down their average vitality as to render them much more liable to serious sickness and death.

This, the most widely prevalent of all nervous disorders in this country, seems to be on the increase. It is very commonly found among persons who take no reasonable recreation—many business men, among others—and the loss of time and incapacitation for work are very great, often weeks and months at a time.

As to the extent to which minor ailments exist, no statistics are available. Doctor Castle, of Cincinnati, estimates, from an experience of many years in the medical supervision of institution employees and general practice, that there is an average of at least three days' time lost annually for each person in the population because of such minor ailments. Similarly, Dr. J. F. Morse, of the Battle Creek Sanitarium, who has had a long experience in dealing with a large number of cases, estimates that the average "well man" loses on an average five days a year from work on account of headaches, toothaches, "colds," and similar minor ailments which do not come under the head of any of the diseases reported.

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[a] Letter from Dr. Chas. H. Castle.

SECTION 2.—*Preventability of minor ailments.*

That almost all minor ailments can be avoided is scarcely to be doubted. Doctor Gulick is "inclined to believe that something like nine-tenths of all the minor ailments that we have, and which constitute the chief source of decreasing our daily efficiency, could be removed by careful attention." "With the removal of nine-tenths of our disabilities and the conservation and further development of our natural powers," he adds, "the average person can increase his efficiency 100 per cent, that is, he can be twice as effective. This does not refer to doing merely or mainly twice as much work, of course, but by making less mistakes, and by working at a higher degree of speed when he does work. By working under conditions so that the work does not need to be repeated, the whole total will be much greater—I think not too much to say twice as great—as under ordinary conditions."

Minor ailments are preventable by leading a reasonably hygienic life and by revising the modern gospel of "hustle"—which latter usually means crude, imperfect, and slovenly work, whether mental or manual. The prevention of these diseases would "cost" nothing—for it costs nothing to stay well.

If, again, we consider the experience of those who have made a serious attempt to avoid minor ailments, their preventability becomes clear. Personally, I have known of scores of cases in which the tendency to catch cold has been almost completely overcome. In one case a physician, who as a boy had suffered from continual colds and hay fever, succeeded, through the simplification and control of his diet, in attaining almost complete emancipation, which has lasted over forty years. Another physician reports that for ten years, during which time he has taken special means to produce complete evacuation, he has not caught a single cold. A large number of cases observed are of persons, physicians as well as laymen, who have taken the outdoor cure for tuberculosis or nervous prostration. These persons not only succeeded in combating these serious troubles, but in completely freeing themselves from liability to colds. Evidently, if the outdoor life had been adopted simply as a preventive of colds, it would have prevented originally, as it cured subsequently, their more serious disorders.

CHAPTER V.—*Prevalence of undue fatigue.*

SECTION 1.—*Strength, endurance, and fatigue.*

When a person is free from all specific ailments, both serious and minor, he usually calls himself "well." There is, however, a vast difference between such a "well" man and one in ideally robust health. The difference is one of endurance or susceptibility to fatigue. Many "well" men can not run a block for a street car or climb more than one flight of stairs without feeling completely tired out, while another "well" man will run 25 miles or climb the Matterhorn from pure love of sport. The Swiss guides, throughout the summer season day after day, spend their entire time in climbing. A Chinese cooly will run for hours at a stretch. That the world regards such performances as "marvelous feats of endurance" only shows how marvelously out of training the world as a whole really is. In mental work some persons are unable to apply themselves more than an hour at a time, while others, like Humboldt or Mommsen, can work almost continuously through fifteen hours of the day.

As Mosso [a] and others have proved, muscular fatigue is a chemical effect, due to the circulation of " fatigue poisons " in the blood. This has been strikingly shown by experiments by Weishardt and others on dogs; when blood is transfused from an exhausted dog to a " frisky " one, the latter immediately wilts and becomes fatigued like the former, although he has not exerted himself in the least. In order to reduce fatigue, therefore, we should keep down fatigue poisons. It is not unlikely that almost all poisons produce fatigue, whether the poisons come from infections, from drugs, from impure or excessive food, from bad air, or from exertion.

It should be noted that endurance is a quality quite distinct from strength.[b] Strength is measured by the utmost force a muscle can exert once; endurance by the number of times it can repeat an exertion requiring a specified fraction of available strength at the start. Thus, if each one of two men is barely able to lift a dumb-bell weighing 100 pounds, their strengths are equal, but if one of them can raise a dumb-bell weighing 50 pounds 20 times, while the other can raise it 40 times, the latter may be said to have double the endurance of the former. Another mode of expressing the same thought is that endurance is measured by the slowness with which strength decreases through exertion.

SECTION 2.—*Alcohol and fatigue.*

Of all poisons in ordinary use, alcohol and tobacco are the most common. That alcohol increases fatigue is now commonly recognized by athletes. "Alcohol gives no persistent increase of muscular power. It is well understood by all who control large bodies of men engaged in physical labor that alcohol and effective work are incompatible." [c]

One of the most interesting features of the cycling sport, when long tours were the fashion a few years ago, was the fact that the wayside seller of drinks found himself forced to supply chiefly " temperance drinks." The cyclists discovered that they could not make their " century runs " on alcoholic beverages. Two friends report that they stopped for refreshments and drank beer. Resuming their ride they found it hard to propel the machine, and both imagined some obstruction had lodged in the gears. Only after having dismounted and satisfied themselves to the contrary did they come to the conclusion, whether rightly or wrongly, that the resistance was in their own legs and was due to the beer.

Careful experiments with alcohol in relation to fatigue have been reported by Rivers,[d] who shows that alcohol diminishes the capacity

[a] See Fatigue, English translation. New York (Putnam), 1904.

[b] See Irving Fisher: The Effect of Diet on Endurance. (Publications of Yale University, Transactions of the Connecticut Academy of Arts and Sciences; New Haven, 1906, p. 1.)

[c] The Liquor Problem, a summary. Report of subcommittee of committee of fifty on physiological aspects of the liquor problem. New York (Houghton-Mifflin), 1905.

[d] W. H. R. Rivers: "Influence of Alcohol on Fatigue, etc." London (Edward Arnold), 1908, pp. 89–90.

for exertion. Experiments carried on by Professor Aschaffenburg with four typesetters, all users of alcohol, showed that on days when Greek wine, containing 18 per cent of alcohol, was given the men there was considerable diminution of the capacity for work. On the alcohol days two of the men did decidedly less work, while the work of the remaining two was marked by great irregularity.

The injury from alcohol is mitigated, but not excluded, through combination with sugar, malt, and other beneficial ingredients, as in beer.

SECTION 3.—*Tobacco and fatigue.*

As to tobacco it is a common observation that smoking interferes with one's "wind" in running. The poisons which probably bring about this result include others than nicotine. Possibly the most important poison is carbon monoxide, which has a great affinity for the iron in the blood.[a] When the smoker "inhales," this poison, probably joined with others, enters directly into the blood stream.

In an experiment carried on by Doctor Lombard, "smoking was found to have a very depressing effect upon the strength of the voluntary muscular contractions. * * * Undoubtedly the effect of tobacco to lessen the voluntary power is due to its influence upon the central nervous system."[b]

It is the testimony of many users of tobacco that the habit of smoking leads to nervousness and disinclination to exertion directly after smoking.

Experimentation has shown that smoking increases blood pressure. The greater resistance to circulation offered by the blood is presumably due to the excitation caused by the introduction into the blood stream of foreign matter from the tobacco. There is reason to believe, though the fact has not been established, that endurance is lessened by high blood pressure.

SECTION 4.—*Diet and fatigue.*

Poisons may also enter the system through food. Many poisons come from diseased, contaminated, or adulterated foods; but they may also be due to excess of food or wrong preparation of foods, and especially to the decomposition of protein (the principal ingredient of white of egg and lean meat) in the colon. The absorption of such poisons causes auto-intoxication.

It has long been known by physiologists that the putrefaction in the intestines is the putrefaction of protein. But only recently have they raised the question whether a reduction of the protein element of food would be feasible and whether the resulting reduction in putrefaction and auto-intoxication might not be advantageous.[c] These questions are still under debate, but the trend of physiological opinion is increasingly in favor of protein reduction. Practically this means a lessening of the consumption of lean meat and eggs.

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[a] "The toxicity of tobacco smoke," The Lancet, CLXXV, 1908, p. 104.

[b] Warren P. Lombard, M. D., "Some of the influences which affect the power of voluntary muscular contraction." Journal of Physiology, Vol. XIII, 1892, p. 48.

[c] See C. A. Herter, "Bacterial Infections of the Digestive Tract," New York (Macmillan), 1907.

Evidence has accumulated, though it has not yet been put in proper experimental form for absolute proof, that auto-intoxication is not only an exceedingly common affection, but also the chief cause of undue fatigue. Most persons know the heavy feeling and disinclination to exertion which generally accompany constipation, and, on the other hand, the relief which comes with a complete evacuation.

Leaving auto-intoxication aside, Professor Chittenden is of the opinion that waste products from combustion of protein are probably responsible for fatigue. Whatever the explanation, Professor Chittenden found in his classical experiment[a] with a squad of soldiers, that strength and endurance were increased by a reduction of the protein. Thirteen soldiers were placed for six months on a diet containing a much smaller quantity of protein food than what is prescribed by ordinary dietary standards and containing only one-third of what is demanded by common American usage. Professor Chittenden's results are gaining recognition, but they will need to be further tested before any unanimity of opinion can be reached.

Analysis of the diet of several hundred vegetarians shows that on the whole they are lower in protein than the average American. Comparative experiments on 17 vegetarians and 25 meat eaters in the laboratory of the University of Brussels have shown little differences in strength between the two classes, but a marked superiority of the vegetarians in point of endurance. The average superiority was 53 per cent. The vegetarians recuperated from fatigue more quickly than the meat eaters.[b] To what extent, if at all, the superiority of the vegetarians was due to vegetarianism as such, and to what extent to the fact that they made a more moderate use of protein, can not be exactly determined, although the evidence indicates that the lower protein is the essential factor. The virtues and drawbacks of vegetarianism as such have as yet received almost no scientific study.[c] Professor Chittenden is now engaged in such a study.

In another experiment, comprising 49 subjects and contrasting those on high and low protein diets, it was found that the low protein subjects had greater endurance.[d] For instance, the test of "deep-knee bending" showed that whereas the high-protein subjects could seldom exceed 400 or 500 times, the low-protein men could frequently exceed 1,000, and in one case reached 2,400.

The writer has in his possession several hundred unpublished individual records of men on a low and high protein diet. These, on the whole, seem to show a considerable superiority in endurance among those using the lesser amounts of protein. But while the trend of evidence seems at present to favor a reduction in protein, the question is not yet settled.[e] There exist many conspicuous cases of high

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[a] See Russell H. Chittenden, "Physiological Economy in Nutrition," New York (Stokes), 1904, and "The Nutrition of Man," New York (Stokes), 1907.

[b] "Enquete Scientifique sur les Vegeteriens de Bruxelles," par Mlle. le Dr. J. Ioteyko and Mlle. Varia Kipiani, Bruxelles (Lemartin), 1907. For English abstract see "Diet and Endurance at Brussels," Science, Vol. XXVI, 1907, pp. 561–563.

[c] An exception is Caspari, "Physiologische Studien über Vegetarismus," Bonn (Hager), 1905; see also Gautier, "Diet and Dietetics," English translation, London, 1906.

[d] Irving Fisher, "Influence of flesh eating on endurance," Yale Medical Journal, March, 1907.

[e] See, for example, Prof. F. G. Benedict's paper on "The nutritive requirements of the body," American Journal of Physiology, Vol. XVI, 1906, pp. 409–437.

protein and great endurance. A striking instance is that of the pedestrian Weston.

In an experiment on nine healthy students, the writer found that thorough mastication seemed to cause a gradual decrease in protein. The significance of the experiment lay in the improvement in physical endurance of eight of the men, which increased over 90 per cent in five months. The ninth man—the only one whose protein was not greatly reduced—failed to improve in endurance.[a]

SECTION 5.—*Exertion and fatigue.*

Exertion increases combustion of oxygen, and the capacity for exertion is intimately related to the completeness of this combustion.

Experiments in artificially administering oxygen to athletes have been made in England by Hill, Flack, Pombrey, and others.[b] Following these, a series of experiments in swimming recently took place at Huntington, L. I. The swimmers to whom oxygen had been administered surpassed their nonoxygenized competitors as well as their own previous natural records. Doctor Bising, who carried on the experiment, states that the effects of oxygen inhalation are useful for short efforts only. At most the oxygen exercises its influence for not more than three minutes.

Perhaps the most important of the common influences affecting the capacity to resist fatigue is physical exertion. It is well known that a man "in training" has greater endurance than one who attempts exertion without previous systematic exercise or training. In general, it may be said that a person in the "pink of condition" is fit not only for physical but also for mental exertion. The great majority of adults are far from being "in condition," suffering either from lack of exercise or from too much exercise. The ordinary man errs either in one direction or the other. The brain worker lives too sedentary a life, while the manual worker, through fatigue caused by long hours, is in a continual state of overexertion. Could these conditions be remedied, endurance, as measured by capacity to withstand prolonged strains, might be greatly increased.

Experiments have shown that physical endurance can be doubled by dietetic causes alone, or doubled by exercise alone. By both together it is not unlikely that it could be tripled or quadrupled. But when it is said that the endurance, or capacity for exertion, of the ordinary healthy man could be thus multiplied, it is not meant that the hours of his daily work, or even his daily output of work, could be increased in such a ratio. What it does mean is the removal of the fatigue limit, a freer and more buoyant life, and a visible increase in the quantity and quality of work per hour.

In an ideal life fatigue would seldom be experienced. But in most lives, unfortunately, fatigue is a daily experience. A workman who gives intelligent and systematic care to the body writes that when after a long day's work the factory whistle blows at night he, unlike his fellows, feels as fresh as when he began work in the morning. Workmen can by such self-care mitigate some of the evils of

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[a] Irving Fisher, "Effects of diet on endurance," loc. cit.

[b] British Medical Journal, 1908, August 22, p. 499; also August 29, p. 578, Journal of Physiology, 1908, XXXVII, 77–112.

"the long day." But they are amply justified, both in the interest of their own and of national efficiency, in continuing their efforts toward a shortening of the work day.

SECTION 6.—*The working day.*

The present working day is a striking example of the failure to conserve national vitality. In order to keep labor power unimpaired, the working day should be physiological—i. e., it should be such as would enable the average individual to completely recuperate over night. Otherwise, instead of a simple daily cycle, there is a progressive deterioration. A reduction in the length of the work day would be a chief means of improving the vitality of workmen, as well as the worth of life to them.

The fatigue of workmen is largely traceable to their long work day and serves to start a vicious circle. Fatigue puts the workman in an abnormal frame of mind. He seeks to deaden his fatigue by alcohol, tobacco, exciting amusements, and excesses of various kinds. The momentary relief which he thereby obtains is purchased at the expense of an increasing susceptibility to fatigue, resulting sooner or later in complete depletion of his vital energies and in the contraction of tuberculosis or other fatal disease. The decrease in the length of the working day has not diminished the total output.

An instance in which the eight-hour day superseded the nine-hour day with entire success is the case of the Salford Iron Works, of Mather & Platt, at Manchester, England, which changed to the eight-hour day in 1893. As the firm's products were subject to keen competition in both home and foreign markets, it was obliged to look carefully after the labor cost, and its conclusion that such cost did not increase in consequence of the reduction in working hours was reached after extremely accurate comparisons by accountants, who of course took into consideration the saving in consumables, wear and tear, fuel, etc. The Bureau of Labor inquired of Messrs. Mather & Platt if they were still on the eight-hour basis, and received a reply dated May, 24, 1904, in which they stated that—

> our experience since the first year in which it (the eight-hour system) was tried has fully borne out the conclusions then arrived at, and we are fully satisfied that as regards the comparison between eight and nine hours per day the balance of advantages is in favor of the shorter period.[a]

> In 1894 the hours of labor of about 43,000 workmen in British government factories and workshops were reduced to forty-eight per week. Of this number, 18,600 received a reduction of five and three-fourths hours a week, and 24,300 had their time reduced two and one-half hours a week. With no change in piece rates the workmen were able to earn as much as formerly. Day workers received an increased hourly rate of pay to make their earnings per week of forty-eight hours equal to those per week of fifty-four hours. It was not found necessary to increase the number of day workers.[b]

In 1899 the owners of the great Zeiss optical goods factory at Jena, Germany, introduced the eight-hour day and then made careful records of the results. In 1903 it was announced that although the aggregate number of hours worked had decreased 15 per cent the output per hour had increased 16.2 per cent.[c]

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[a] New York Labor Bulletin No. 25, June, 1905, p. 240.

[b] Board of Trade Labor Gazette, July, 1905, reported in New York Labor Bulletin No. 28, March, 1906.

[c] New York Labor Bulletin, No. 25, June, 1905, p. 240.

At Liege it was found in a sulphuric acid establishment similar to a foundry [a] that shortening the working day from eleven hours to ten, from ten to nine, and so on gradually down to seven and one-half, resulted, in each case, in an increase of the output.

The Solvay Process Company, of Syracuse, installed in 1892 a system of three eight-hour shifts in place of the two previous shifts of eleven and thirteen hours, respectively. It was stated by the assistant general manager in 1905 that the change had considerably lessened the wear and tear on the men, and that they could be called on to do their work at their highest state of efficiency, which had not been possible on the two-shift basis. President Hazard of the company writes:

> In general, I can say that the results of the change from a twelve-hour shift to an eight-hour shift were very satisfactory and have continued to be so. While the immediate result was to considerably increase the cost per unit of product, the efficiency of the men gradually increased, so that at the end of about one year the first increase has been overcome and the cost per unit of product fell to a point even lower than had been obtained under the twelve-hour shift, and further the time consumed per unit of product has since been so reduced that we are today and for some time have been operating with a smaller number of hours per unit of product than we had under the twelve-hour shift.

Further proof of the benefits of the change to the three-shift day is furnished by the records of the Solvay Mutual Benefit Association for 1891 and 1904. The days lost per man by sickness each year fell from seven and one-half days in 1891 to five and one-half days in 1904.

It is not maintained that in all cases productivity will be as great in eight hours as in nine. Cases to the contrary could also be cited. The point to be insisted upon is not that it is profitable to an employer to make the work day shorter, for often it is not, but to show that it is profitable to the nation and the race. Continual fatigue is inimical to national vitality, and however it may affect the commercial profits of the individual it will in the end deplete the vital resources on which national efficiency depends.

In the interests of this efficiency, a longer time at noon for lunch is usually necessary. The present economy of lunch time is shortsighted, tends to food bolting, indigestion, a drowsy and tired afternoon, and inferior work. This has been shown by actual experience.[b]

The accident bulletins of the Interstate Commerce Commission contain frequent records of disasters caused by the long hours of railway employees. In a recent bulletin, No. 27, two collisions are attributed to the mistakes of employees who have been on duty much longer than the instinct of safety should allow. Collision No. 3,[c] which killed 2 and injured 13, was due to the mistake of a station operator who had been on duty from 7 a. m. to 3.30 p. m. and who had returned to duty at 8 p. m. The collision took place at 12.30 a. m. the next morning.

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[a] See L. G. Fromont, "Une Experience Industrielle de Reduction de la Journel de Travail," Brussels, Solvay Institute, 1906.

[b] See especially description of a French experiment cited by Hubert Higgins in Humaniculture, New York (Stokes), 1906.

[c] Accident Bulletin No. 27, January to March, 1908.

SECTION 7.—*Importance of preventing undue fatigue.*

The economic waste from undue fatigue is probably much greater than the waste from serious illness. We have seen that the average serious illness per capita is usually about two weeks each year. This is about 4 per cent of the year. Expressed differently, about 4 per cent of the population is constantly sick.

On the other hand, the number that suffer partial disability through undue fatigue certainly constitute the great majority of the population. No observer can fail to conclude that this is true of the American working, business, and professional classes, and the latest word among the students of school hygiene is that it is true to a large extent even among children. If therefore we assume that only 50 per cent of the population is suffering some impairment of its best powers through undue fatigue, we are on safe ground. The extent to which the power of this supposed 50 per cent of the population is impaired must certainly exceed 10 per cent. When we consider that young men, supposed to be perfectly well, have the enormous room for improvement indicated in this chapter, and when we consider the gratifying results of experiments with a shorter work day it will be seen that the true impairment is probably several times 10 per cent. Yet if only 50 per cent of the population are suffering an impairment equal to only 10 per cent of its working powers, the result is equivalent to 5 per cent of the population suffering total impairment which is more than the 4 per cent impairment from serious illness.

The relatively slight impairment of efficiency due to overfatigue leads to more serious impairment. Just as minor ailments prove to have an unsuspected importance when considered as gateways to serious illness, so the inefficiency from fatigue is vested with great significance as the first step toward minor ailments. Obviously if overfatigue could be reduced to a minimum, this reduction would carry with it the prevention of the major part of minor ailments, which in turn would lead to a great reduction in more serious illness, and this finally would lead to a great reduction in mortality. A typical succession of events is first fatigue, then colds, then tuberculosis, then death. Prevention, to be effective, must begin at the beginning.

But prevention is merely the first step in increasing the breadth of life. Life is to be broadened not only negatively by diminishing those disabilities which now narrow it, but also positively by increasing the cultivation of vitality. Here we leave the realm of medicine and enter the realm of physical training. The first and lowest step is gymnastics. This is valuable—far more so than the ordinary sedentary man who neglects it realizes—but it is after all a kind of medicine not altogether pleasant to take and far less valuable to him who takes it than are athletic sports, which constitute the next highest stage. Beyond athletic sports in turn comes mental, moral, and spiritual culture, the highest product of health cultivation. It is an encouraging sign of the times that the ecclesiastical view of the Middle Ages, which associated saintliness with sickliness, has given way to modern "muscular Christianity," typified in Young Men's Christian Associations with their gymnastics and athletics. This is but one evidence of the tendency toward the "religion of healthymindedness" described by Professor James. Epictetus taught that no one could be the highest type of philosopher unless in exuberant health. Expressions of Emerson's and Walt Whitman's show how much their spiritual exaltation was bound up with health ideals. "Give me health and a day," said Emerson, "and I will make the pomp of emperors ridiculous." It is only when these health ideals take a deep hold that a nation can achieve its highest state of development. Any country which adopts such ideals as an integral part of its practical life philosophy may be expected to reach or even excel the development of the health-loving Greeks.

The means of securing both the negative prevention of invalidity and the positive accumulation of vitality will form the subject of Part III.

Part III.—METHODS OF CONSERVING LIFE.

CHAPTER VI.—*Conservation through heredity.*

SECTION 1.—*Heredity and environment.*

That the waste of life through preventable disease and death is enormous appears clearly from the facts already cited. The practical problem is this: If such waste is really preventable, what are the conditions necessary to make prevention an accomplished fact? There are two main conditions. First, a general desire for improvement; second, a general knowledge of how to secure that improvement.

Once the general public recognizes the needless waste of vitality, it will not be content until that waste has been eliminated. To such an awakening the American instinct of economy is in itself a powerful spur. Practical men are coming to consider it "good business" to take some care of their own vital resources. As this view gains ground, habits and fashions will adapt themselves to the change. The folly of the man who loses his health in the pursuit of wealth, and then for the rest of his days spends his wealth to win back health, is beginning to be appreciated.

Human vitality depends upon two primary conditions, heredity and hygiene, or conditions preceding birth and conditions during life. In other words, vitality is partly inherited and partly acquired.

It is well known that cultivated plants and animals have been greatly changed and developed by breeding. "The original apple, as offered by nature to mankind, was the small, sour, bitter crab of the forest, unpleasant, indigestible, innutritious. * * * In 1710 Doctor Davenant, a writer on political economy, estimated that the average weight of dressed cattle did not exceed 370 pounds. * * * In 1846 McCullock stated that 'at present the average weight of cattle is estimated at or about 800 pounds.'"[a]

Human heredity is now dependent on haphazard selection. Little attention is paid by those who contemplate marriage to the question of how much stamina will be transmitted to the next generation. The story was told of a famous dog fancier who, when asked why he paid so much attention to his dogs but delegated the care of his children to nurses, replied: "My dogs have a pedigree." Human pedigrees, no less than canine, rest on a physical basis; yet genealogical records of human beings, while they have much to say of social position, have very little to say of physical capacity or intellectual ability. Those who, like Galton and Pearson, believe in a science of eugenics, hope that the day will come when pride of inheritance will include as im-

[a] See Dr. Edward Jarvis, Political Economy and Health, Fifth Report, Mass. Board of Health, 1874. Doctor Jarvis adds that human life is as "expansible" as animal life.

portant, if not as the chief items, physical, mental, and moral stamina. A tendency in this direction can be discerned. When the nobility commanded the reverence of all classes, quite irrespective of ability, commoners, however well endowed by nature, could never obtain the same respect. But to-day the English House of Commons is more honored and respected than the House of Lords.

Once the importance of a physical pedigree comes to be rated at its true value, a man's pride in his own inheritance will show itself in a correlative feeling of responsibility for future generations. For the sake of children yet unborn, men and women will set for themselves physical ideals of the highest order.

SECTION 2.—*Eugenics.*

The whole question of race improvement through heredity constitutes the subject-matter of the new science of eugenics. The devotees of this science are at present engaged in studying the laws of heredity in all its aspects. The Mendelian doctrine of heredity, with the theories of Darwin and Weissman, are some of the topics which need to be studied in reference to their practical application.

Until more results have been obtained, it would be premature to make great claims for the possible future usefulness of applied eugenics. A word may be said to prevent misunderstanding as to its aims. Many have supposed that the object of eugenics was to bring about suitable marriages by compulsion of the Government. Such a proposal would not only be absolutely impracticable, but would defeat the very ends aimed at. Marriage, above all human choices, must, as a rule, be left to the individual, guided by his ideals alone. By the change of these ideals alone can the character of marriages be influenced. Sir Francis Galton, the founder of the science of eugenics, expects intelligent public opinion to be the chief guide in marriage. Just as the union of brother and sister is tabooed, and the marriage of even first cousins[a] is eyed askance—whether justly or not does not matter—so, if the aims of eugenists are carried out, an obviously unhygienic marriage will be frowned upon. It was somewhat in this way that the ancient Sparta raised its vitality to a high point of physical excellence.

Galton has pointed out[b] that present restrictive rules of marriage selection are endured without any sense of loss of privilege or freedom. For example, members of the European nobility are, in their marriage choice, restricted almost wholly to fellow-aristocrats; yet so much has this restriction become a part of their ideal and creed that the narrowness of the range of choice is not usually realized.

Even granting that some marriages are studiously calculated to win money or title, a much stronger or more pervasive, although unconscious, influence is exerted by the ideals which young men and women at marriageable age have formed of what their companions for life should be. Nothing is more certain than that if from

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[a] In at least 20 States the marriage of first cousins is forbidden by law. An excellent discussion of this subject is contained in "Consanguineous Marriages in the American Population," by G. B. L. Arner, Ph. D., New York (Longmans), 1908.

[b] "Sociological Papers," London (Macmillan), 1906, Vol. II, p. 12.

childhood they were trained to regard vitality as the first essential in an ideal man or woman, this would influence their personal fancy. Health, beauty, and vitality are natural objects of admiration and love. Titles, wealth, and other extraneous attractions are not. To lessen the public esteem for these, and to increase the esteem for natural human merit, will tend to increase not only the number of healthy marriages, but the importance of the rôle played by normal love. If, therefore, eugenic ideals ever hold sway, love marriages will not only continue to exist, but will become more frequent. Love is a primal and natural instinct, and the more natural men and women are, and the more highly they esteem natural vitality, the more will they be guided by mutual attraction.

If a considerable percentage of the population once shall come to regard vitality as an essential endowment, the effect on mating will be felt in two ways: First, a larger percentage of healthy persons will marry, leaving a larger percentage of unhealthy persons single; second, healthy persons will mate with each other, and unhealthy persons, in so far as they marry at all, will do so among themselves. Of mixed matings there will be a smaller number. Both of these results will tend gradually toward the improvement of the race. That the first—the increased proportion of marriages among the healthy—will do so, is obvious. The second—the marriage of like with like in respect to health—would, it seems probable, operate to increase the number of progeny of healthy couples and decrease that of the unhealthy, especially after the first generation.

Since athletics have come into vogue it is well known that the athletic ideal has led to athletic mating. The tendency of the present devotion to athletics must be to elevate the respect for physical prowess. The high esteem entertained in Japan for physical training and for hygiene as a guarantee of the fighting power of the country, constitutes an object lesson, if not a warning, to Americans who wish their country to be the peer of the best. It would be folly, of course, to expect any change in ideals so complete that there would not be numerous exceptions to hygienic mating, but, once the bulk of mankind are guided by a truer principle in forming marriages, the effect on racial development will make itself distinctly felt within a generation. As President Roosevelt has said: "The preservation of national vigor should be a matter of patriotism." Some persons would even make it a matter of religion.

SECTION 3.—*Eugenics and law.*

It is possible, however, that governmental interference with the birth rate may in future be employed to a limited extent. Two ways have been suggested: One is for the Government to give prizes or bounties to couples that conform to certain specified standards in the same way as the French Government has encouraged the increase of population by offering inducements to couples of the poorer class who raise seven or more children.[a]

The second is to forbid alliances among criminals, paupers, and the feeble-minded. These classes fall under the tutelage of the State,

[a] In 1889, fathers of seven children were made exempt from payment of the personal property tax. This exemption was in 1890 limited to fathers who paid taxes of not over 10 francs each.

and thereby forfeit their right to free choice. Already Indiana,[a] Connecticut,[b] Michigan,[c] and other States in this country, have passed laws of this sort.

Indiana extends the prohibition to all persons suffering from transmissible disease of any sort. This prohibition is called into daily operation in that State. It is in the power of the Indiana state board of health to raise by degrees the standards of health demanded of those who desire license to marry, a provision that aims directly at the improvement of human vitality in the State. Indiana has gone even further and has recently provided[d] that confirmed criminals, imbeciles, idiots, and rapists, procreation by whom is deemed inadvisable by experts, shall be unsexed (or "sterilized") by surgical operation. Under this law over 800 prisoners have been sterilized to date.[e]

The experiments started in Indiana and other States will be interesting to watch, and promise an improvement over the conditions which have prevailed too often in the past. Professor Brewer, of Yale, tells of a case in Connecticut some years ago where a feeble-minded pauper woman, kept as a public ward, was admired by a half-witted farmer living in an adjoining town. A selectman of the town maintaining the woman "to get rid of her support" encouraged their marriage. His short-sightedness, even from the standpoint of immediate money economy, to say nothing of racial economy, became apparent when, a few years later, she and her husband and three idiotic children drifted into the poorhouse of the husband's town.

That laws like the ones discussed, but of gradually increasing severity, will become common in the future seems likely; and, as Professor Lankester has remarked, humanity will probably submit in the future to communal restriction of the right to multiply with as good grace as it has given up the right to rob and to rape.[f]

The effect of restrictions upon free right of marriage is discussed by Doctor Hurty, secretary of the Indiana state board of health, as follows:

> It seems most essential and necessary that we have laws for the prevention of the production of the unfit if society is to be saved from destruction. Modern hygiene, under which I include in this instance all such benevolent institutions as insane asylums and institutions for the feeble-minded, is extending the duration of life of the dependents and deficients, and it might be added that the humane and hygienic care in the prisons is extending the duration of life of the delinquents. In Indiana the life duration of the insaue has been exteuded eight years within the last two decades. This slight extension means a very considerable burden upon the people, and if this class of deficients is unrestricted we can readily see what a burden time will place upon society. The production of the unfit must cease if charity and hygiene continue. Otherwise it seems certain that society will be swamped.

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[a] Indiana Laws of 1905, chap. 126, H. 118, sec. 3.

[b] Connecticut Statutes (revision of 1902, sec. 1354), forbid the marriage of epileptics.

[c] Michigan forbids the marriage of epileptics.

[d] Indiana Law of 1907, chap. 215, H. 364.

[e] Letter from Dr. J. N. Hurty.

[f] E. R. Lankester, "The Kingdom of Man," London (Constable), 1907, p. 41. The recent report of the Royal Commission on the Care aud Control of the Feeble Minded recommends such restriction.

While institutional treatment of the insane is right and proper from a humanitarian point of view, by bringing an increase in the average insane lifetime it adds to the public burden and enlarges the figures of the living insane. Mr. Sanborn estimates the average insane life in Massachusetts at thirteen years, of which at least three years occur, on the average, before hospital treatment is applied. He adds:

I suspect we have come nearer to statistical accuracy on this question in Massachusetts than has been reached in any region of equal population anywhere. The world has beeu gradually coming round to the conclusious reached by the late Dr. Pliny Earle (of Northampton) and myself, viz, that the chauges in the social and sauitary conditions of all civilized countries have increased the number (proportioned to population) of new cases of insanity, while the improved treatment of patients in the meantime has made the average insane life longer than formerly, and that in spite of the well-known increase in forms, like paresis and epilepsy, which may soon end fatally.

Interesting records exist of two families of criminals, the so-called "Jukes" and the "Tribe of Ishmael." From the one man who founded the "Juke" family came 1,200 descendants in seventy-five years; out of these, 310 were professional paupers, who spent an aggregate of two thousand three hundred years in poorhouses, 50 were prostitutes, 7 murderers, 60 habitual thieves, and 130 common criminals.

Dugdale[a] has estimated that the "Juke" family was an economic loss to the State, measured in terms of potential usefulness wasted, costs of prosecution, expenses of maintenance in jail, hospital, and asylums, and of private loss through thefts and robberies of $1,300,000 in seventy-five years, or over $1,000 for each member of the family.

Similarly, the "Tribe of Ishmael," numbering 1,692 individuals in six generations, has produced 121 known prostitutes and has bred hundreds of petty thieves, vagrants, and murderers. The history of the tribe is a swiftly moving picture of social degeneration and gross parasitism, extending from its seventeenth-century convict ancestry to the present-day horde of wandering and criminal descendants.[b]

Had the original criminals in the "Juke" family and the "Tribe of Ishmael" been sterilized under some law like that of Indiana, this country would not only have been spared a widely disseminated criminal, epileptic, and immoral strain, but would have saved hundreds of thousands of dollars paid out for criminal suits and for institutional care, to say nothing of the expenses still to come from the incapacity and criminality of future generations.

These cases present only one side of the case. Over against them may be set illustrious families in which great intellectual ability and moral worth have been passed on through many generations. Such a one is the Hohenzollern family. In commenting on the frequent occurrence of persons of surpassing mental and moral attainments in this family, Woods[c] says: "It is particularly suggestive of what might be done with the human race were mankind ever so inclined." A similar example from a different walk in life is afforded by the Darwin family, where for four generations in direct line (Erasmus, Charles,

[a] R. L. Dugdale: "The Jukes," New York (Putnam), 1877.

[b] Oscar C. McCulloch, "The Tribe of Ishmael," a study in social degeneration, "Report of Fifteenth Annual Conference of Charities and Corrections, 1888," pp. 154–159.

[c] F. A. Woods, "Mental and Moral Heredity," New York (Holt), p. 79.

George, Horace, and Francis) as well as in collateral lines (e. g., Frances Galton) scientific ability of the first rank has been manifest.[a]

President Roosevelt has pointed out that "race suicide" is a sign and accompaniment of coming decay. Mere numerical increase is not the whole solution, however; there must be improvement in quality also. A race that can not hold its fiber strong and true deserves to suffer extinction through race suicide. The decline of our Puritan stock, so well pictured in the genteel but worn-out Pyncheon family of Hawthorne's novel, need not alarm us if we can replace it with a new influx from the West or from the vigorous stocks of Europe.

There is one problem which concerns both the numbers and the quality of future generations, which hitherto has received practically no attention except in a partial report upon the subject in Australia. This problem is, What is now and will be the effect of voluntary childlessness upon the size and character of the birth rate and upon morals? It would be useless, here, however, to do more than mention this as one of the gravest problems in the world to-day. Ronald M. Byrnes[b] shows that the fecundity of Yale graduates has steadily diminished from 5.7 for the graduates of 1701–1791 to 2.0 for those of 1867–1886. This reduction is much greater than the reduction for the whole country, which is reported by the census to be from 5.8 in 1790 to 4.6 in 1900. Degenerates have large families. From a study of 150 degenerate families, Doctor Tredgold[c] found that the average number of children per family was 7.3, while the normal average for the country at large (England) is 4. These figures do not specify the frequency of marriage among degenerates or the mortality. Unless the one is sufficiently low and the other sufficiently high, there must follow deterioration. General reduction of the birth rate may end in depopulation. It is not unlikely that this phenomenon will be the stimulus needed to bring about practical eugenic reforms.

What eugenics might possibly accomplish is indicated by one writer in the following manner: "How rapidly the race would advance if mankind should resolve: 'The next generation must be born with healthy bodies; must be nurtured in healthy physical and moral environments; and must be filled with the ambition to again give birth to a still healthier, still nobler, generation.'"[d]

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[a] The Frances Galton Laboratory for National Eugenics, University of London, is soon to issue a "Treasury of Human Inheritance," containing pedigrees illustrating inheritance of various types of intellectual ability, of tuberculous stocks, of epilepsy, physical depravity, etc.

[b] Yale Review, November, 1908.

[c] W. C. D. Whetham, "Inheritance and Sociology," the Nineteenth Century, January, 1909.

[d] Louis R. Ehrich, "Posteritism," an address delivered at the dedication exercises of The Century Chest, Colorado Springs, Colo., 1901. For literature on eugenics, the reader is referred to the following papers and the references therein contained: "Eugenics, Its Definition, Scope, and Aims," by Francis Galton, American Journal of Sociology, Vol. X, pp. 1–6, 1904. "The Scope and Importance to the State of the Science of National Eugenics," by Karl Pearson, Oxford University Press, England. "Social Darwinism," by D. Collin Wells, Papers and Proceedings of the American Sociological Society, Vol. 1, University of Chicago Press. "The Human Harvest," by David Starr Jordan, Boston (American Unitarian Association), 1907. "Eugenics," by Prof. Albert G. Keller, Yale Review, August, 1908. "A First Study of the Statistics of Pulmonary Tuberculosis," by Karl Pearson, Drapers Company, Research Memoirs, London (Delau & Co.), 1907.

CHAPTER VII.—*Conservation through public hygiene.*

SECTION 1.—*Municipal hygiene.*

Whatever improvements in heredity may sometime be achieved, the benefits of their influence can be enjoyed only by future, perhaps distantly future, generations. We of the present generation have to take our heredity as we find it. We can not follow the advice of the humorous philosopher to begin life by selecting our grandparents; but, through hygiene, we can make the most of our inherited endowment. Even such a limited effort offers large—amazingly large—rewards.

Ideal conditions for health comprise a pure and disease-free atmosphere in which to live and work; pure food and a pure water supply; protection from infection and accident; and a proper adjustment of work, rest, and amusement. Existing conditions are not only far from ideal, but also far from what might easily and speedily be attained.

That the saving power of hygiene is great is now universally recognized; that it will be greater is the hope and belief of those most competent to judge. "If hygiene were able to prolong life when it was little developed, as was the case until recently, we may well believe that, with our greater knowledge of to-day, a much better result will be obtained."[a]

There is every reason to believe that human beings are as amenable to cultivation as other animals and plants. Professor Graves, of the Yale Forest School, states that by protecting trees from infection their lives may often be prolonged a century. Domestic animals are equally dependent on care. Doctor McGee states that the growth of a colt may be stopped by giving it alcohol.

The methods of securing improvement in health conditions may be roughly classified under three groups: Public hygiene, semipublic hygiene, and personal hygiene. The first group refers to activities of the government; the second refers to activities of the medical profession and institutions such as hospitals, sanatoria, schools, and factories, and to voluntary associations; the third group deals with the private life of the family and the individual. Each of these three groups covers phases of all three branches of hygiene, viz, the hygiene of environment, nutrition, and activity.[b]

In this chapter we have to deal with public or governmental hygiene. This branch has been chiefly concerned with pure air and pure food and with organisms producing epidemic diseases. Boards of health are a recent invention, and in this country they have as yet been only imperfectly developed. They can never become the power they should be until, first, public opinion better realizes their usefulness and the fact that their cost to the taxpayer is saved many times over by the prevention of death and disease; second, more and better health legislation is enacted—national, state, and municipal; and, third, special training is secured for what is really a new pro-

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[a] Metchnikoff, Prolongation of Life, p. 144.

[b] Since this report was written there has appeared the excellent and inspiring "Civics and Health," by William H. Allen, Bureau of Municipal Research, New York (Ginn), 1909.

fession, that of public health officer—a profession already recognized in England by a special diploma.

The health officer should be supported entirely by the salary of his office and should be absolutely prohibited from practicing medicine. Not only are his duties incompatible with practice quite as much as those of judges with the practice of law, but if he gives them proper attention there is no time for other duties. No court, police, or fire department, or other agency of government, can be more important to a people than this under the complex conditions incident to the rapid growth of both rural and urban populations. It is so important that this be realized that it is worthy of serious consideration as to whether it would not be better for all imperfectly equipped and supported health boards in this country to resign—so that the authorities and people would be brought face to face with the knowledge that they have no real protection except in the emergency of an epidemic—than for existing conditions to continue.

Laboratories, research workers, statisticians, and other facilities for the performance of a national board of health's duties should be furnished in proportion to the power and wealth of the Government and the vast interests it would protect and promote. The results of its scientific and collective investigations should be constantly utilized in promoting health in the army and navy, in protecting streams and soils from pollution, in the construction of interstate waterways, in the reclamation of swamp lands, and in other public works involving health problems of supreme importance to the future of this country.[a]

Public hygiene may be studied under three heads, corresponding to our governmental divisions: Municipal hygiene, state hygiene, and federal hygiene.

Municipal hygiene and sanitation are placed largely in the hands of city boards of health, or equivalent organizations, which have power to issue sanitary regulations, abate nuisances, and even to punish infractions of their instructions by fine and imprisonment. Sanitary legislation is a product of advanced civilization. To-day not a city is without a board of health. The powers of these boards have grown, till to-day they are by no means inconsiderable; yet they must be given even greater authority, if our municipal sanitary conditions are to be what they should. Public apathy and political interference are such that health authorities can not enforce their orders. In addition to the acquirement of greater power, city health boards often need purification of motive and the banishment of political bickerings and personal jealousies.

The simplest ordinances along the line of public hygiene are those against spitting, which now remain so largely unenforced.

The smoke nuisance is another seemingly simple form of air vitiation that is receiving attention to-day. Sulphuric acid is apparently the most injurious factor. The corrosion of stone structures suggests the irritation resulting in catarrh and other respiratory mucous-membrane troubles.[b]

The effect of the introduction of closed sewers on the reduction of tuberculosis should not be overlooked. By closing sewers, impure gases have been confined, thereby removing an important source of air pollution. Some cities realize that pure air spells life and health to its inhabitants, and that pure air is a possibility only when atmospheric particles of soot and dirt are removed.

Regulations governing garbage removal, notification and isolation of disease, and the like are as a rule enforced, and new regulations are being issued constantly. Substantial progress is shown each year

[a] Letter from Dr. J. N. McCormack.
[b] See Journal American Medical Association, September 7, 1907, p. 813.

in the purification of city water supplies, in the improvement of sewage disposal, and in the bettering of drainage conditions. Streets are more thoroughly cleaned and the elimination of public and private nuisances continues without ceasing.

Our city streets have received greater care since Colonel Waring organized his "white wings" brigade in New York City a dozen years ago, thus proving the great effectiveness of clean streets in the elimination of disease. The probable elimination of the horse from our city life, through automobiles, the betterment of our trolley systems, and the introduction of subways (especially freight subways) will go far to improve our city atmosphere. The problem of city air will be half solved when our streets reach their proper state of cleanliness. The gradual elimination of the horse will tend not only to produce cleaner air, but also to reduce the dangers from flies. It is in horse manure that the common horsefly ("typhoid fly") chiefly breeds. Doctor Howard attributes the termination of typhoid in certain parts of Washington to the displacement of the horse by the automobile.

Only within a dozen years has the dread importance of insect carriers of disease been realized. That mosquitoes carry malarial germs; that flies are the propagators of typhoid, cholera, and other infectious diseases; that rats breed the fleas which transmit to man the dreaded Asiatic plague [a]—all this knowledge is of recent origin.[b]

Well people are sometimes carriers and distribute typhoid, diphtheria, etc., a fact which complicates public-health regulations.

The simple reporting of all contagious disease to the health authorities immediately on its appearance is often the means of preventing an epidemic.

Smallpox epidemics are prevented both by quarantine and vaccination. Because of the outcry against compulsory vaccination, in some places the responsibility for vaccination is being thrown upon the individual. This is true in Leicester, England, and in Minnesota. Doctor Bracken, secretary of the Minnesota State Board of Health, writes that since the quarantine has been abandoned and the individual has had the option of being vaccinated or not, a larger number has been vaccinated and smallpox has diminished.

We are awaking to the importance of securing for ourselves, through our city health agencies, a pure milk supply. Great danger is also present in cream, butter, cheese, and ice cream. More than one city has inaugurated a policy of careful supervision of the milk supply. Montclair, N. J., has a well-considered plan in operation whereby the bacterial count of each dairy is public to inquirers at the board of health. This species of publicity will some day prove a strong incentive to a better milk supply. Some cities have even established municipal stations, where during the summer season sanitary milk may be purchased at cost. Doctor Goler, of Rochester, has emphasized the fact that "We employ physicians to cure children af-

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[a] See Rupert Blue, "The prophylaxis and eradication of plague," California State Journal of Medicine, Vol. V, 1907, p. 304.

[b] A full treatment of the subject of insect-borne disease has been prepared by Dr. L. O. Howard, Chief of the Bureau of Entomology of the Department of Agriculture, for the National Conservation Commission. See also Charles Harrington, M. D., "Practical Hygiene," Third Edition, Philadelphia, (Lea), 1905, pp. 637-660.

fected by the diarrheal diseases from dirty milk, while we permit the sale of dirty milk from filthy cattle." [a]

In Rochester, through the efforts of Doctors Goler and Roby, a few municipal milk stations were established in 1897, where during July and August milk in nursing bottles could be bought at a low price. The reduction in the Rochester infant death rate between 1897 and 1906 is doubtless due to many other conditions than the quality of milk; but the special attention drawn to the milk supply and the consequent education of the public, which probably boiled its milk when it could not get it clean, would explain a considerable part of the reduction.[b]

The interrelation of the purity of milk supply and infant mortality is shown by the following excerpt from Doctor Woodward's annual report as health officer of the District of Columbia for the year 1907:

> High as is the infantile mortality even now from diarrhea and inflammation of the bowels, it is far below the figures that formerly prevailed.
>
> The only explanation for the fall in the death rate from infantile diarrhea that I have been able to discover is the enactment on March 2, 1895, of the law regulating the sale of milk in this District and the establishment of dairy and dairy-farm inspection under the provision of that law.

The weekly report of the Cincinnati board of health for August 21, 1908, states:

> As far as we know, there has been but one death among the babies whose food supply has been obtained from the milk stations. When it is taken into consideration the large number of children we have supplied, this statement is certainly a fitting commentary upon the value of a bacteria-free and chemically pure milk.

At the recent International Congress on Tuberculosis, one delegate reported an experiment in England which has not yet appeared in print. In Liverpool the local government board tried the experiment of using pasteurized milk. The amount of illness and death in that city from children's tuberculosis is very great, yet among 1,800 children who were given pasteurized milk and who were carefully watched every week not a single case of tuberculosis developed, which seems to prove conclusively that children's tuberculosis is entirely preventable by the use of pure or pasteurized milk. This is interesting, though at variance with former opinion regarding bovine tuberculosis in children.

In this section should also be mentioned such municipal health agencies as public baths, bacteriological laboratories, and the distribution and administration of specific antitoxin, vaccine, and free medical service. Municipal inspection of local abbatoirs is also important, inasmuch as federal inspection covers only establishments engaged in interstate business.

Most important of all is the matter of preventing pollution of the water supply of cities, a topic that will receive fuller treatment later in the chapter.

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[a] See George W. Goler, M. D., "Municipal regulations of the milk supply," paper at the meeting of the American Medical Association, 1907, p. 2. For conclusions based on a study of 330 milk-borne epidemics, see George M. Kober, M. D., "Milk in relation to public health," S. Doc. No. 441, Government Printing Office, 1902.

[b] See George W. Goler, M. D., "Origin, development, and results of municipal milk work in Rochester, N. Y.," Maryland Medical Journal, June, 1906.

The needs of municipal as of state hygiene are not so much new laws as better men to enforce existing laws and an aroused public opinion that will result in the appropriation of funds sufficient to enable health authorities to perform their duties in an efficient manner. Larger appropriations will doubtless bring better men into the public-health service.

SECTION 2.—*State hygiene.*

State hygiene is necessary to supplement municipal hygiene for many reasons. One is that the country often has no other sort of sanitation possible. Another is that the city is dependent on the country for its water, milk, and other supplies. Dr. W. G. Daggett, of New Haven, has emphasized the fact that in origin typhoid is largely a rural disease and must be combated by controlling rural privies and other sources of infection.[a] A competent authority asserts that "old country wells, so much valued by their owners, are a positive menace to public health. Fully 50 per cent of these are unfit for use." Much of the typhoid fever brought by milk is readily traceable to such wells.

In the control of the liquor traffic the State and local units should cooperate.[b]

A state, rather than a municipal, function is the regulation of woman labor and child labor. The growth of public opinion on this point has been rapid. In order to make the working hours meet the physiological requirements of women, two special conditions should be attended to. One is her monthly period; the other is childbearing. The neglect of both is responsible not only for physical impairment of factory women, but also for their inability to perform their functions as mothers of the race. Doctor Stiles, of the Public Health and Marine-Hospital Service, has suggested a very sensible remedy to meet the first of these conditions, and one which has met with the approval of many factory employers. It is that each woman shall have the right, once every month, to walk out of the factory without any questions being asked, and without loss of the day's wages. The matter is further simplified in factories provided with a matron and a rest room. In respect to the second condition—that of childbearing—the evidence is clear and convincing. Women, on account of their imperfectly developed muscular system and more delicate physique, are unfitted for hard work; nor should they be obliged to work steadily in a sedentary position, especially at the sewing machine, or other occupations involving the use of the lower extremities. Special protection should be extended to them during the childbearing period. It is a matter of constant observation that women who have to deny themselves proper rest and care during the next six weeks after confinement are very liable to suffer from hemorrhages and chronic uterine diseases, while miscarriages and premature births are not infrequent results of overwork.[c]

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[a] "The prevention of typhoid fever," Proceedings Connecticut Medical Society, New Haven.

[b] See "Regulation of the liquor traffic," Annals American Academy of Political and Social Science, November, 1908.

[c] George M. Kober, M. D., "Industrial and personal hygiene," "Report of Committee on Social Betterment of the President's Homes Commission," Washington, 1908, pp. 67–68.

The employment of mothers shortly before and after the time of childbirth is prohibited in a number of European countries. American statutes, however, are almost silent on the question.[a] Professor Jevons went so far as to advocate the enactment of legislation forbidding the employment of mothers till their youngest children were at least 3 years old.

The beneficial effect on the mother, and especially on the child, of forbidding the factory to her just before and after childbirth has been proved many times. The case of M. Dollfus, a large employer of women at Mulhausen, in Alsace, has been repeatedly cited. He required mothers to remain away from their work for a period of six weeks after childbirth, during which time he paid them full wages. The decrease in infantile mortality in the first year of the experiment was from more than 40 to less than 18 per cent.[b]

The waste of vitality from unphysiological hours of work is most striking in the case of children. It is hardly to be questioned that children need longer hours of rest and sleep than adults, and that their immature bodies are much closer to the fatigue limit. A little girl in a southern mill replied to Mrs. Van Vorst's query whether she were often tired, "Why, I'm always tired." Except in unusual cases and for limited periods, child factory labor can not be defended on any hygienic grounds. The period of preparation for a wholesome, healthy life should be left free from the cares and evil physical influences of factory life. No child should run the risk of serious accident, deformity, dwarfing, or mental stunting through factory labor. It is true that in the South child labor is often the lesser of two evils, the other being the life on a farm where, through soil pollution, the child contracts hook-worm disease. Here the abolition of child labor should be preceded by the abolition of hook-worm disease.[c]

Closely connected with the restriction of child and woman labor is factory legislation in general, dealing with hours of labor, factory hygiene and sanitation, and dangers from industrial accident.

The hours of labor have for a century been on a gradual decrease. A hundred years ago fourteen and fifteen hours were by no means uncommon. The first public action regarding hours of labor was taken by President Van Buren in 1840, when he set ten hours as the limit of the working day in all government establishments. Thirty years later this was lowered by Congress to eight hours. Since 1850 the fight has been waged for a shorter day, both by labor unions and individuals; and the statutes of nearly all States contain legislation limiting the working hours of women and children in all industries, as well as of all workers in certain industries, especially mining, railroading, and the more dangerous manufacturing industries. The Aldrich report of 1890[d] estimated that the American working day averaged eleven and four-tenths hours in 1840 and ten hours in 1890. Tables based upon annual reports of the Bureau of Labor show a reduction of about 4 per cent from 1890 to 1903,[e] while it is the

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[a] John Spargo, "The Bitter Cry of the Children," New York (Macmillan), 1906, pp. 44–45.

[b] Spargo, loc. cit., pp. 50–51.

[c] See "Report of the Surgeon-General of the Public Health and Marine-Hospital Service for 1907," relating to the investigations of Doctor Stiles.

[d] "Report on Wholesale Prices and Wages," 1890, Vol. I, p. 178.

[e] T. S. Adams and Helen L. Sumner, "Labor Problems," New York (Macmillan), 1905, pp. 516–518.

opinion of United States Commissioner of Labor Neill that the figures for 1908 would unquestionably be lower than for 1903, as the struggle for the shorter working day has been making steady progress each year.[a]

The frightful losses of life and efficiency from preventable accidents can be prevented only by state legislation.[b]

Our employer's liability acts are very unsatisfactory, because they fix no scale of compensation for injuries, but necessitate expensive lawsuits to determine in each case the sum due. A president of an insurance company doing a large business in employer's liability insurance states that of the sums they pay employers only one-quarter reaches the injured employee, who is forced to spend the other three-fourths in litigation. In England the workman's compensation acts have substituted a system of specific sums for which the employer is liable. Not only does this result in larger indemnities reaching the injured, because suits are ordinarily unnecessary, but it has the further beneficial effect of reducing the number of accidents by inducing employers to instal safety devices.

The regulation not only of the place of work, but also of the dwelling place, has come to demand action on the part of the State as well as of the community. The growth in tenement-house legislation during the past ten years has been most encouraging. Standards of sanitation for our large buildings have been raised; provision is increasingly made for good light, air, water, and for protection from fire; and the "rookeries" of old are giving way to improved tenements. Yet New York City still contains 300,000 rooms without a window.[c]

SECTION 3.—*Federal hygiene.*

The regulation of disease has increasingly become a national function. The exclusion of immigrants with infectious diseases is only one instance of this; another is the work of our Public Health and Marine-Hospital Service, which not only regulates the spread of disease from State to State, and regulates by quarantine the entry of disease from without the country, but also assists local health boards in their fights against epidemics and disease scourges. Epecially is this true in coastal cities. The Marine-Hospital Service assisted New Orleans to eliminate yellow fever and San Francisco to rid itself of bubonic plague. In addition, this service treats 50,000 seamen of the merchant marine each year, conducts a large number of hospitals and relief stations, examines pilots, life-saving crews and revenue-service men, and conducts a well-equipped hygienic laboratory.

Federal, state, and municipal sanitation are all concerned with the hygiene of transportation. To-day almost the whole American public travels, and it is therefore most important that the conveyances

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[a] See Bulletin of the Bureau of Labor, No. 77, July, 1908, pp. 6–7; also, "First Annual Report on Changes in Rates of Wages and Hours of Labor in Massachusetts," Boston, 1908, pp. 592–3.

[b] The Federal Government can of course reach interstate railways. A law passed during the last session provided for a safe locomotive ash pan. Previous laws provide for automatic couplers, air brakes, etc.

[c] A. Jacobi, M. D., "The physical cost of women's work," Charities, February 2, 1907.

which they occupy, whether carriage, cab, street car, or railway train, shall be sanitary in respect to ventilation, cleanliness, toilet facilities, spittoons, dust, smoke, sleeping-car accommodations, and the like. In smoking cars, in addition to the smoke itself, the floors are usually befouled with tobacco juice and other expectoration. The efficient remedy here as elsewhere is to be found, not simply in providing facilities for cleanliness, but in fostering the present public sentiment against spitting and other untidy habits. A physician of experience maintains the opinion that "foul air in railway trains and street cars is the cause of serious poisonings called 'colds' and 'grip,' particularly in those many trains where air from the smoker sweeps through passenger cars."

The development of our national quarantine methods is indicated in the following paragraph from Surgeon-General Wyman, of the Public Health and Marine-Hospital Service:

> Until 1893 there was, properly speaking, no national system of quarantine. The colonies had their own quarantine regulations before the formation of the Union, and from that event to 1893 quarantine was left to the care of state governments and by the latter to county governments or to municipalities, as the case might be. There was, indeed, national legislation, but all the acts of Congress up to 1893 relating to quarantine specially provided that the said national measures were in aid of the state and local authorities. Whatever opinions may have been held by members of the national legislature, quarantine was permitted to be exercised by the States as a police function, and even in the present law, which gives national supremacy, it is provided that assistance shall be given the States or municipalities by the government authorities, the supremacy of the latter being asserted only when the state or local authorities fail or refuse to enforce the uniform national regulations.[a]

To-day efficient inspection at our various ports of entry and at disembarking stations abroad keeps out many cases of disease each year, while the quarantine cordon thrown around ports or municipal quarters affected by infectious disease is an important factor in stamping out such disease.

Federal meat inspection chiefly benefits the foreigner, but the administration of the pure-food laws is of value to our own people.

There are two functions of Federal Government which now are very imperfectly served and which might be made of paramount importance. They are the functions of research and of the dissemination of information. A poultry raiser, or a cattleman, or a farmer can secure scientific information to guide him in his selections of fowl, or stock, or seed by applying to the Government at Washington, but information on how to raise children has up to this time been neglected by our Government. Nothing is to-day more significant of future progress than the fact that the President, the President-elect, and many Congressmen are so strongly in favor of a greater federal organization of health. Through the dissemination of information throughout the country, through enactment and administration of effective regulations concerning pure food, inspection of meat, and exclusion of foreign diseases, through research, statistics, and through better standards for state and municipal health service, a great economy of national vitality can be effected. Washington, our national capital, might be made by the Federal Government a model city of

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[a] Walter Wyman, M. D., "The quarantine system of the United States," The Sanitarian, November, 1897, p. 3. See also James W. Garner, "Federal activity in the interest of the public health," Yale Review, 1905–6, p. 181.

healthfulness, as a preliminary to its becoming a model in every other way.

Army hygiene in time of war is most important. The lack of such hygiene has shown grave consequences. In the Boer war the British army in South Africa lost more men from typhoid fever than from wounds received in battle.[a]

The efficiency of Japanese hygiene manifests itself in the fact that General Oku's army of 75,000 during the recent Russo-Japanese war had but 187 typhoid fever cases in a seven months' active campaign.

The Japanese reduced their dysentery cases from 12,052 in the Chinese war to 6,624 in the Russian war; their cholera cases from 7,667 to none; and their malaria cases from 41,734 to 1,257. This was in spite of the fact that their army in the Russian war was three times the size of that employed in the Chinese war.[b]

The crying need of better statistics is trenchantly expressed by Dr. Cressy L. Wilbur, Chief of the Division of Vital Statistics of the Census Bureau, whose words should be read and pondered by everyone who desires to see any intelligent conservation of our vital resources:

> Sound vital statistics are the indispensable basis of modern sanitation. A nation that does not consider it necessary, or that is not able, to provide adequate means for registering the births of its own children, or for officially recording the deaths of its citizens, can hardly be supposed to attach sufficient value to human life to enable sanitary measures for its conservation to be adequately carried out.
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> For the continental United States in 1907 somewhat less than one-half of the total population (48.8 per cent) was represented in the registration area from which returns of deaths were received by the Bureau of the Census. For the remaining 51.2 per cent of the total population of the United States, estimated at 43,774,724 persons, either very imperfect laws were in effect, giving only partial registration, quite worthless for statistical purposes, or else the conditions in many States might be represented by the statement made by one of their health officers, that it buries its dead people with no more ceremony than it buries its dead dogs.
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> As for the registration of births, a measure which is so supremely important for the knowledge of infant mortality, for the protection of infant life, and for securing the legal rights of children, not a single State in the Union nor a single city of any considerable size makes positive claim that it registers as many as nine births out of every ten that occur. Even the city of Washington, whose law for this purpose is a direct enactment of Congress, does not arise above this low limit of efficiency. The total number of births must be known before one can make a computation of infant mortality which will be comparable with the rates given in the vital statistics of all civilized nations except the United States. This ratio depends upon the comparison of deaths of infants under 1 year of age with total births, and, as we have no exact registration of births, we can not present these important statistics.
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> In the consideration of the effect of such an important disease as tuberculosis upon the people of the United States there is no means of knowing, within a very wide margin of error, exactly how many persons die from this cause in this country during any year. We have registration of deaths for about one-half of the population only, and the very dissimilar conditions of life and the large proportion of colored population in the unregistered half seriously interfere with any attempts to guess at the exact number. Estimates have varied from 138,000 to 200,000. The truth probably lies somewhere between them, but we certainly ought to have an exact record of the facts and not be obliged to depend upon mere guesswork in entering upon an important sanitary undertaking, such as the prevention of tuberculosis.

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[a] Ditman, loc. cit., p. 17.

[b] L. L. Seaman, "The Real Triumph of Japan," New York (Appleton), 1906, pp. 106–7.

On the question of army diet, see Blackham: British Medical Journal, 1908, August 8, p. 311.

We are laboring, in conjunction with the American Medical Association, the American Public Health Association, and with the sanitary officials of as many States as we can interest, to extend the registration area as rapidly as possible. Ohio has just adopted an excellent law, which takes effect next year. Not a single State in the South has yet succeeded in reaching a satisfactory standard—not one of them in fact has even passed an adequate law. We are depending upon the voluntary cooperation of the States. The Government has no power, it would seem, to collect the statistics or to secure the proper registration of births and deaths by its direct action. If all of the important interests involved could be awakened to the importance of this matter, if Congress would take a direct interest in the accomplishment of this work, we could secure fairly complete registration of deaths for the United States within the next ten years.[a]

CHAPTER VIII.—*Conservation through semipublic hygiene.*

SECTION 1.—*Medical research and instruction.*

By semipublic hygiene is meant hygiene through nongovernmental institutions, including institutions for medical research, the medical profession, hospitals, sanatoria, associations, schools, and factories.

Medical discoveries have usually been made in the laboratories of medical schools, universities, and research institutions. The practical value of these institutions is only beginning to be appreciated. The benefits already received from them are great, and the benefits to come will be incomparably greater. One of the earliest medical laboratories, the Pasteur Institute of Paris, has done splendid work during the past two decades in the study of harmful and beneficent bacteria. Of more recent origin are the British Sanitary Institute in London, the Rockefeller Institute for Medical Research, the Memorial Institute for Infectious Diseases at Chicago, and the Nutrition Research Laboratory in Boston, under the Carnegie Institute of Washington. The recent achievement of Dr. Simon Flexner in finding a serum for the treatment of meningitis is but one example of what well-directed research under the auspices of such institutions can accomplish. The crowning achievement of science in the present century should be, and probably will be, the discovery of practical methods of making human life healthier, longer, and happier than heretofore.

The medical schools in this country number 156. They are rapidly advancing, although the great majority are still ill equipped for providing intending practitioners with the most recent and useful knowledge. The future practice of medicine depends more on the character and aims of the medical schools of to-day than on any other factor. At the dedication of the Harvard medical buildings in 1906, President Eliot laid down as the primary duties of that school the study of the prevention of disease and the education of the public. The need of such a school especially devoted to prevention has been fully discussed by Doctor Ditman.[b] Several universities have courses, or are taking steps to give courses in the fields not only of public hygiene and preventive medicine, but also of personal hygiene and home economics.

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[a] Letter from Dr. Cressy L. Wilbur. See also Irving Fisher, "Mortality statistics of the United States census," publication of the American Economic Association, 1899; and R. Dudfield, "A critical examination of the methods of recording and publishing statistical data bearing on public health," Journal of the (Royal) Statistical Society, March, 1905.

[b] See N. E. Ditman, M. D., "Education and its economic value in the field of preventive medicine," Columbia University Press, Vol. X, supp. to No. 3, June, 1908.

One difficulty in establishing such a school is the lack of students who can afford the means or the time to attend. This was the experience of the George Washington University, in Washington, when a course of this kind was offered. For this reason it is gratifying to see that an effort is being made to throw open the research laboratory of the Public Health and Marine-Hospital Service for the use of health officers detailed from their several States and municipalities. In England the degree of D. P. H. (diploma in public health) is given those who meet the high standard set there for health officers.

During the last few years the American Medical Association has been seeking to study, classify, and improve the medical schools in the United States. A large committee, of which the writer is one member, has been appointed by the association to consider methods of securing such improvements as are deemed necessary. It includes in its scope the important but heretofore little appreciated field of medical economics.

SECTION 2.—*The medical profession.*

We come next to the part played by physicians, so far as relates to their "private practice." Their work as public health officers has already been mentioned, and does not concern us here. Their work in the home is of primary importance. It is on the physician that the average man relies for protection when he finds himself in the dread grip of disease.

Private practice comprises two main divisions, surgery and general practice. The first important application of the knowledge of germs was to surgery. Antiseptic surgery, originated by Lord Lister, has resulted in the saving of untold thousands of lives and has led in turn to aseptic surgery, which is still more effective. Not only has it reduced the previous mortality from operations, but it has vastly increased the number and kind of operations which can be performed in cases which under the old régime would necessarily have proved fatal.

Of one of the most recent advances the eminent surgeon Dr. W. J. Mayo writes:

> Second only to the germ theory has been the usefulness of the great discovery of Röntgen and the application of the X-ray to surgical diagnosis. It makes certain the diagnosis in a large number of conditions which were previously a matter of speculation, and enables remedial surgical measures at an early date, lessening mortality and morbidity.
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> Another great surgical discovery is the suture of blood vessels evidenced by the work of Carrel. Its possibilities are astounding. The ability to transplant the kidney of one dog to another and have it continue its function, the amputation of a leg and its resuture, opens up the whole question of the transplantation of sound for diseased organs, especially organs which are double.[a]

In these and other surgical work a certain amount of vivisection is necessary. The present outcry against vivisection is an example of a defective sense of proportion. While needless cruelty should be avoided, the suffering of animals through vivisection, including all cases where the practice has been abused, is as nothing compared with the suffering of human beings which would be caused if all vivisection were abolished.

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[a] Letter from Dr. William J. Mayo.

The progress of antisepsis has so reformed midwifery that puerperal fever, a former scourge of humanity, is now extremely rare. In many cases the child, by being freed from gonorrheal contamination by the mother at birth, has been saved from blindness.[a]

The advance of surgery is shown by the following table of mortality of the wounded in the wars of the nineteenth century. Antiseptic surgery was introduced at the time of the Franco-Prussian war in 1870–1:

	Per cent.
Crimean war, English troops	15.2
French troops in Italy, 1859–60	17.4
German army, 1870–71	11.1
Spanish-American, 1898	6.6
Transvaal, 1900–1901	5.5

In general practice progress is also being made. The use of violent drugs is fast going out of fashion. The recognition of the self-limiting character of most of the acute diseases sounded the death knell of the harsh drugging of the olden time. Laboratory experimentation and careful study as to the physiologic and therapeutic effects of drugs have shown the necessity of subjecting everything material or immaterial, intended for the relief of human ailments, to the crucible of the most rigid scientific scrutiny. This sentiment has grown until in the best medical circles it is properly considered a reproach for a physician to use any preparation without an exact knowledge of its composition and a definite conception of the results expected from its administration. The number of medicines used by physicians is decreasing and will, if the predictions of experts in this field may be trusted, ultimately be reduced to a small fraction of the present pharmacopœia. Many medicines, like quinine and mercury, will of course merit a continuance of use. Syphilis, malaria, hookworm disease, and some other diseases are best combated by drugs.

Serum therapy, although in its infancy as to most diseases, has opened up a field of great promise. For example, antidiphtheretic serum, the one best understood and in most common use, has reduced the mortality in that disease from 50 or 60 to 12 or 14 per cent.[b] Not so much medicines or serums, but hygiene, will probably be the dependence of the next generation of physicians. Possibly the term "medicine" will some day be almost as inappropriate in describing the treatment toward which physicians are tending as the term "leech" now is in describing the physician. The profession has ceased to be hostile to hygienic treatment, and is slowly but surely substituting it for much of the internal treatment formerly employed. The new treatment includes the use of air, light, water, food, rest, massage, mechanical vibration, electricity, exercise, and suggestion, under the names of aerotherapy, hydrotherapy, psychotherapy, etc. These remedies have the great advantage of preventing as well as curing disease.

It only remains for all medical schools and the courses of lectures now gratuitously provided by the American Medical Association for all county medical societies to teach these things in such a thorough and practical way as will reach the whole profession and bring these

[a] Elie Metchnikoff, "The Nature of Man," New York (Putnam), 1903, p. 210.
[b] Metchnikoff, "The Nature of Man," p. 212.

benefactions to the whole people. In proportion as prevention is more important than cure, the rapid advance in the knowledge and practice of preventive medicine will be of value.

"To hygiene belongs without a doubt the place of honor in modern medicine. It is in the prevention of infectious diseases that the interest of the medical art is now mainly centered."[a] The best men are turning to these physiologic methods with enthusiasm.[b] They are learning to take into account the anxiety and other mental reactions of the patient as to what is said in his presence.[c] They are becoming more public-spirited and cooperative,[d] and alive to their responsibility to set patients a good example in living hygienic lives.[e]

The trend toward prevention is indicated in various ways—by the fact, for instance, that some physicians are now employed by families, schools, firms, associations, etc., for the purpose chiefly of preventing rather than curing disease. Women dentists graduating from the University of Michigan have made a practice of attending to children's teeth at a stated amount per month. Employers are increasingly securing the services of competent physicians to care for the health and physical welfare of their employees. This is a preventive measure, and has been found to be a "paying proposition" to the employer because of the resulting enlarged efficiency of the workers.

Their modern fight against tuberculosis has led physicians to a larger use of fresh air in their practice. At first many employed this agent merely as a "specific for tuberculosis," but its utility in all chronic ailments, such as neurasthenia, for instance, was next recognized. Latterly, fresh air has been discovered to be of use in pneumonia and other acute diseases. It is now not unusual to find physicians advising their patients, whether ill or well, to sleep out of doors. There can be no question that man was originally an outdoor animal.

The discovery of the germ origin of Asiatic cholera, tuberculosis, diphtheria, typhoid fever, bubonic plague, influenza, and other diseases, and of the part played by water, impure food, insects, rodents, and other common and almost omnipresent, but hitherto unrecognized, agencies as carriers of disease to man and animals, has awakened a world-wide interest in these subjects which, properly fostered and directed, opens up ever extending possibilities to the humanitarian, the economist, the statesman, and, still more, to the people at large.

The consequence must be a great revolution in medicine in the immediate future. The practice of medicine is destined to become a much more powerful agent than ever before in the suppression and prevention of disease. This result will be reached when the change now going on permeates the rank and file of the profession. It would be a pity if, through undue conservatism of some of its members, the profession should lose some of its prestige hard won during the last generation. Already the ever-present quack is pressing into the inviting field. As the public demands "drugless treatment" and many

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[a] Metchnikoff, "The New Hygiene," Chicago (Keener), 1906, pp. 12–13.

[b] See G. Stanley Hall, "Adolescence," New York (Appleton), 1905, vol. 1, p. 238.

[c] See A. T. Schofield, "Power of Mind," London (Churchill), 1902, 2d ed., p. 277.

[d] See Osler, "Maryland Medical Journal," October, 1905, p. 420.

[e] See Professor Osler's address to St. Mary's Hospital, London, 1907.

physicians fail to see and meet that demand so far as it is rational, the quacks see their opportunity. As a consequence, there is fast developing a species of quack that not only does not use "patent medicines," but condemns their use by regular physicians. Men of this type base their appeals on "naturopathy," become "food experts," prescribe fasting, or two meals a day or five meals a day, give lessons in "deep breathing," conduct outdoor sanatoria, and employ light and air baths, dry cupping, mechanical vibration, intestinal lavage, water cures, electricity, osteopathic manipulations, "divine healing," etc. All these methods have value under certain conditions; the only objection is that when applied by the uneducated they are utilized to poor advantage. The fault lies not in the therapeutic means but in those who use them. Physicians sometimes confuse the two, and make the mistake of opposing the means and user alike. They reject good means of cure because employed by "irregulars."

The result is that the patient sometimes finds the best means of recuperation in the hands not of medical men, but of uneducated "physical trainers." The public will go and should go to those who will render the most effective help. In order that the medical profession may suppress quackery the way must be not to oppose the use of beneficial therapeutic agents in incompetent hands, but to get their use into competent hands by adopting them themselves. There is a quackery that is villainous and injurious. This should be suppressed. But there is another quackery which is well intentioned and which, in spite of ignorance, manages to do some good. The good in it should be appropriated by the profession. By always promptly absorbing the best the profession will be in a position to cast out the worst in "irregular" systems of therapeutics. It may then recover the ground which it has too often lost. There was no reason why it should have lost hundreds of thousands of patients to "Christian Science," except that these patients were for the most part benefited, and greatly benefited, by Christian Science after having received no benefit, and often injury, from the profession. "Easily physicians, without knowing it, can produce sickness by pessimistic prophecies, by anxious looks or words. Thus are diseases suggested (unconsciously) by the physician."[a] Had the profession made use of mental therapeutics not only could they have saved themselves the enmity of these hundreds of thousands, but they could have nipped in the bud the crude metaphysics which teaches the nonexistence of disease and death and the uselessness of any therapeutic agent except those employed by the promulgator. The example of so-called "Christian Science" is only one of several protests, more or less misguided, against the present practice of medicine.

Had all or most members of the profession conceded long ago the harmfulness of many, if not most, violent drugs it might have forestalled the present antidrug movement among the laity. The misguided antivaccination movement is simply the carrying to extremes of the antidrug movement.

The Greeks were probably the most hygienic people that ever lived and they knew nothing of modern scientific medicine, not even of the circulation of the blood. This shows that man's primitive knowl-

[a] Schofield, loc. cit., pp. 215-216.

edge or instincts may be sufficient to enable him to keep and develop health.

The old code of medical ethics, though well-intentioned, was so inelastic and was so susceptible of misconstruction as often to block the way to progress. The magnitude and far-reaching effects of this evil were long ago recognized by leading minds in the profession, and after years of agitation such a revision was unanimously agreed upon in 1903 as makes the modern principles of medical ethics purely advisory and far more liberal than formerly. All restrictions as to consultations were removed, medical societies were thrown open to reputable physicians of every school of practice requiring scientific training, and agencies put in operation for such organization and cooperation and to encourage such liberty of individual opinion as is demanded by the spirit of the age. Under the most active efforts of the medical schools, societies, and journals it will doubtless require years of time for this liberal spirit to reach all members of the profession to the extent which is so desirable. But when this is done and when the public can be made to understand that it has been done the prejudice which has hampered the profession's usefulness, which has made it so difficult to secure and enforce health and medical legislation necessary for the protection of the highest interests of the people, and which has so fostered and given opportunity for quackery, will gradually become ancient history.

A frequent lay comment on some members of the medical profession is that to be true teachers of health they must practice what they preach. A physician can not succeed in controlling drug habits or alcoholism if he has these habits himself. He can not fight "patent medicines" if he uses them himself.[a] He can not effectively fight the social evil if he himself practices abortion. The standards of the profession are high. It is the individual who is at fault. A clergyman who preaches purity from the pulpit while living a double life is disgraced. In the same way, now that physicians are assuming the function of giving instruction in orthobiosis and hygiene, they are being called to account for their own daily lives. Self-interest and altruism alike will lead to needed corrections. The physician in these days of preventive medicine should keep himself well. The challenge "Physician heal thyself" is being followed by the challenge "Keep thyself well." Example more than precept is a principle to be applied here as elsewhere. He can not induce his patients to diet or take exercise if he himself is addicted to the fleshpots and the easy chair. Many a physician to-day loses patients because he and his family are on the sick list, or because as a man he practices habits which as a physician he does not approve.

The physicians in this country now number about 130,000. Their calling is in some respects the noblest in the world to-day. During the present generation the profession has begun to be appreciated for its great services to public and private health and for its self-sacrifice, which is unequaled in any other profession except the ministry. It has now before it an opportunity such as never before existed. Those of us who believe in its mission look forward to incalculable blessings to suffering humanity from greater knowledge better applied.

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[a] See A. Jacobi, Journal American Medical Association, September 29, 1906, p. 978.

SECTION 3.—*Institutional hygiene.*

The large cities have established special contagious hospitals, where prompt isolation of infectious cases may be enforced. The decrease of tuberculosis may be traced largely to hospital isolation.[a] Leprosy was the first disease to be quarantined [b] and its virtual disappearance in civilized countries has been due, at least in the opinion of many authorities, to the strict isolation methods universally adopted.

Of a different kind is the segregation of defective classes of the community. This has led to considerable conservation of their powers and abilities. Institutions for the deaf and blind in the United States contained 14,700 inmates in 1904, and spent for purposes of maintenance over $3,500,000.[c] In these schools the deaf and dumb and the blind are taught trades and professions, their usefulness being thus much enlarged.

The New York state commission on the blind recommended in 1907 a state board for the blind to conduct an employment bureau for the blind of that State, to establish schools, and to put into operation measures for the prevention of blindness. It is pointed out that of the 100,000 cases of blindness in the United States a great percentage is traceable to disease and accident of a preventable character. The commission estimates that of 1,000 cases in New York, 450 were possibly avoidable and 325 (or one-third) certainly so.

For the checking of insanity the crying need is a study of the causes of the malady with a view to its prevention. For, as Doctor Ditman remarks, nine-tenths of the inmates of our insane asylums are incurable, according to our present knowledge. He adds: "What an argument for the prevention of the disease!"[d] Much may be expected from the Phipps fund, for the study of insanity, recently established at Johns Hopkins University.

In the first place, our medical students should receive constant clinical instruction in mental diseases, particularly in their incipient stages. Almost equally important are popular lectures on the preventable and other causes of insanity given under the auspices of medical schools or local boards of health. Such lectures have been given in New York and Boston, and, judging by the attendance, must prove a valuable agency in diffusing a correct knowledge of the cause and development of mental disease. In this education of the laity popular treatises on mental hygiene would prove most helpful. Such a book as Doctor Clouston's "Hygiene of Mind" could, with advantage, be placed in the hands of every young person, and might even be adopted as a text-book in high schools. Certainly the physiology of mind is as deserving of popular consideration as that of digestion, respiration, and the circulation.

By a clearer insight into the beginnings of mental disease, gained through the popular lecture and a nontechnical literature, society will become so far enlightened that intelligent personal prophylaxis

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[a] See Newsholme, "Phthisic death rate," Journal of Hygiene, July, 1906.
[b] See J. M. Eager, M. D., "The early history of quarantine," Yellow Fever Institute Bulletin No. 12, pp. 4–5.
[c] Census report on "Benevolent institutions," 1904.
[d] Ditman, loc. cit., p. 46.

may be anticipated.[a] A knowledge of danger is the surest means of guarding against it. "The most obvious line of attack must be in the direction of the four great etiological factors of insanity, heredity, alcohol, syphilis, and environment. Abstractly considered these four causes are preventable or removable."[b]

As an intermediate step between home and hospital, the sanatorium offers both cure and prevention. Many tuberculosis sanatoria will take patients only in the incipient and early stages of the disease. Sanatoria are used by many as places of recuperation. The tired business man and the nervous housewife find at the sanatorium the quiet they need, and a week or two of rest enables them to escape threatened serious ills.

Many public institutions, in response to popular demand, are to-day installing methods and equipment that are essentially preventive. More than one department store in the large cities filters its air in order that patrons and clerks shall not feel oppressed by vitiation of the atmosphere. An indirect result is the prevention of tubercular and other diseases. A leading hotel in Philadelphia has pitched tents on its roof, where a large colony of well people—not sick—sleep out of doors, and the same hotel utilizes its roof in winter for a skating rink. Mothers' clubs are an increasing factor in the spread of a knowledge of hygiene. Recently a case came to light of a new member of a mothers' club who was feeding her 5-months-old baby on sausage, tea cake, etc., and giving it drugs when she wanted to go out. She was greatly surprised when informed of the wrong she was doing.

Growing interest in the science of home economics, already referred to, is an indication of our increasing realization of the importance of healthful homes in the community. While the number of schools and colleges which offer courses in higher domestic science, and in what might be called "true home economics," is growing, they are nevertheless still comparatively few. More teachers should be equipped with scientific knowledge regarding modern sanitation in order that they may give practical courses in grammar and high schools, and higher instruction should include the topics of hygiene and sanitation. Home making may be studied in many details, such as the construction of healthful houses, the purification of food and water supplies, and the cleansing of cities, whereby the enlistment of both boys and girls in all lines of home and municipal hygiene can be secured.

The churches are now joining in the health movement. The lead has been taken by the Rev. Elwood Worcester and Rev. Samuel McComb at the Emanuel Church in Boston. Trained physicians are employed for diagnosis and for general advice, but great emphasis is laid on the power of suggestion and of Christian self-control over bodily ills. The object is to get both patient and physician to stop "thinking sick and talking sick," as Doctor Goler has put it.

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[a] A book which brings the subject home with unusual force to the ordinary reader is an autobiographical sketch by a recovered patient, "A Mind that Found Itself," by Clifford W. Beers, New York (Longmans, Green), 1908.

[b] Charles P. Bancroft, M. D., "Hopeful and discouraging aspects of the psychiatric outlook," address at meeting of American Medico-Psychological Association, Cincinnati, 1908.

SECTION 4.—*School hygiene.*

In every progressive country to-day the hygiene of school life is coming to be regarded of paramount importance. At the International Congress on School Hygiene, in London, August 5–10, 1907,[a] there were in attendance at least 500 delegates, representing the governments of the world and societies devoted to the advancement of human welfare, and in addition there were 1,500 individuals interested in the improvement of the health of school children and all that this implies. The fact was brought out at the congress that European countries, notably Switzerland, Germany, France, England, and Scotland, are doing more than the United States in the medical inspection of schools and that they are seemingly making plans for the improvement in every direction of the hygienic conditions of school life.[b] Even in Italy the leading statesmen are apparently convinced that the matter of chief importance at the present moment in their educational work is to place it, from start to finish, upon a hygienic basis.[c]

It is the unanimous opinion of all students of the matter that the neglect of the hygiene of school life in the larger sense is, first of all, more or less disastrous to a considerable proportion of the pupils.[d] With us, as well as in most European countries, children are compelled by the state to attend school for a number of years. Many of them suffer constantly from defective vision, hearing, and respiration, from nervous overstrain, and from other ailments which are greatly aggravated by the confinement and stress of school life.[e] Pupils are always exposed to infectious diseases. It is no unusual thing in our country to see a contagious disease sweep through a whole school so rapidly that the local board of health can hear of it and order the school closed only after the harm has been done.

Great as is the injury done by the spread of infectious diseases to children thus massed together in schools, the injury resulting from imperfect seating, lighting, ventilation, and sanitation of school buildings is still more serious. In every part of our country, as well as in the progressive countries of Europe, those familiar with

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[a] The proceedings of the congress contain papers by distinguished physicians and educators upon every phase of the hygiene of school life. Existing evils are pointed out and remedies suggested. Summaries of the papers may be found in the Nineteenth Century, September, 1907, pp. 388–394.

[b] In addition to papers presented at the International Congress on School Hygiene, see the following: A series of articles in the School Review (University of Chicago) for 1907, by Prof. Hermann Schwartz, entitled "The study of experimental pedagogy in Germany." Many articles in the magazine Zeitschrift fur Schulgesundheitspflege show the great interest in Germany in school hygiene. Professor Binét, of Paris, has established a laboratory for the study of childhood in relation to educational work, and he will give particular attention to problems concerning physical defects and mental and moral shortcomings. For other such institutions see The Psychological Bulletin, Vol. VI, March 15, 1909, pp. 84–103.

[c] See, for example, Professor Garlanda's "Il Terzia Italia," in which he shows the only way in which Italy can regain her old-time vigor and efficiency.

[d] See M. V. O'Shea: "Dynamic Factors in Education," New York (Macmillan), 1906, Part II, where the whole subject is discussed.

[e] See Oppenheim: "The development of the child," Chap. V. Also Tyler: "Growth and education;" Burbank: "The training of the human plant;" Burk: "From fundamental to accessory," etc.; Pedagogical Seminary, Vol. VI. Kræplin: "A measure of mental capacity," Popular Science Monthly, vol. 49.

the situation are appealing most urgently for improvement in the physicial basis of education. This is not the place to recite the disabilities which are said by men competent to speak on the subject to result from keeping children for at least eight years in confinement and at hard mental labor under conditions that waste their vitality and develop bodily defects and habits prejudicial to health. The list of such disabilities is a long and impressive one.[a] Unfortunately, we do not, as a people, sufficiently appreciate that the character of social life with us is changing rapidly, and that consequently our children are particularly susceptible to certain diseases and defects; to wit, those arising from the adoption of an indoor life of comparative muscular inactivity, with greatly increased demands made upon particular organs, such as the eyes and the brain.

Doctor Cronin, of New York, maintains that in a school population of 650,000, 30 per cent of the children were from one to two years behind their proper class. Ninety-five per cent of these backward children were so principally because of defects of eye, ear, nose, or throat, which could easily be detected and remedied through effective medical inspection. Experiments at home and abroad have proven beyond any doubt that the majority of children of this sort, when given proper medical treatment, improve markedly in intellect and general conduct. The State attempts to educate these children, but its effects are to a large extent wasted. Doctor Osler calculated that in the special city to which reference has been made there was, on account of a lack of medical supervision of educational work, a yearly financial loss of $1,666,666; and of course the loss which came from moral deviation due to defective physical functioning was of far greater importance. Doctor Osler said recently, in effect, that he considered it of greater importance to the nation that the question of sound teeth be intelligently considered than that the consumption of alcohol be restricted, important as the latter problem is. In similar vein, Doctor Newton reports a case of an old, unhygienic school building in a small town being fitted up with a ventilating system, with the result that the cost of the improvement was saved in a short time in salaries that otherwise would have been paid to extra teachers for taking the place of those made sick by the foul air in the building.

We now know the major effects at least on intellect and temperament of sense defects, adenoids, decaying teeth, and minor physical deformities; and we also know how such deviation from normality can be readily and inexpensively detected and remedied,[b] but there are whole States where no advantage whatsoever is taken of this knowledge, and in practically every State in the country there are communities in which absolutely no attention is paid to any of these matters. The people go on in traditional ways, trusting to luck and disregarding the changes taking place in society.

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[a] See Shaw: "School hygiene;" Keating: "Mother and child;" Ballantyne, in the Lancet, Vol. 2, 1890; Bancroft: "Physical Education Review," Vol. VII; Rowe, "The lighting of schoolrooms;" Burrage and Bailey: "The Sanitation and decoration of school buildings." The Magazine of School Hygiene, published under the direction of the School Hygiene Association, contains in each issue articles showing the evils resulting from unhygienic conditions in the schools.

[b] See, for example, two books by Doctor Warner, of London: "The Study of Children" and "The Nervous System of the Child." The city of Chicago maintains a department for the study of backward and defective children in the public schools.

The health of our school children, then, should be conserved by a system of competent medical inspection[a] which should secure the correction of defects of eyes, ears, teeth, as well as defects due to infection or malnutrition. In Europe—

all the investigations disclosed an astonishing amount of ill health among school children; and though the variations from the normal were found to differ in degree, they were on every hand alike in kind. In nearly every instance they were more pronounced in girls than in boys, and were often most manifest in scholars of the better social classes. Thus there were discovered the following percentages of morbidity among school boys: In Great Britain, 20; in Denmark, 29; in Germany, 30; in Copenhagen, 31; and in Sweden, 37. The perceutages noted among the girls were: In Great Britain, 16; in Copenhagen, 39; in Denmark, 41; in Lausanne, 43; in Germany, 50; and in Stockholm, 62—an average morbidity for boys of 29 and for girls of 42 per cent.[b]

Similar results have been reached in certain cities of the United States. A "committee on the physical welfare of school children" in New York City examined New York school children and found that[c]—

66 per cent needed medical or surgical attention or better nourishment.

40 per cent needed dental care.[d]

38 per cent had enlarged glands of the neck.

31 per cent had defective vision.

18 per cent had enlarged tonsils.

10 per cent had postnasal growths.

6 per cent were undernourished.

Dr. Walter Cornell has been making an extensive study of eye strain among school children. These were his findings:[e]

The relationship of poor vision to scholarship was studied in 219 children. As will be noticed, the difference in marks between those with normal and those with bad vision is greatest in arithmetic and spelling, which studies require more extensive use of the blackboard.

Scholarship percentages obtained.

Children with—	Arithmetic.	Geography.	Spelling.	Average.
Normal vision	79	69	76	75—
Fair vision	70	71	77	73+
Bad vision	66	70	71	69

In New York City 29.5 per cent of 79,069 children examined suffered from defective vision. In London 26 per ceut of 20,000 children examined by eight

[a] See Gulick and Ayres. "Medical Inspection of Schools," Russell Sage Foundation Publication, New York, 1908; see also "The Psychological Clinic," especially Vol. ii, No. 8.

[b] G. Woodruff Johnson, M. D., "Effects of school life on children's health," North American Review, vol. 182, p. 831.

[c] Ditman, loc. cit., p. 41.

[d] This seems a low estimate in spite of the fact that it does not include all cases of decayed teeth, but only those that have been neglected. See Dr. William R. Woodbury, "The People's Disease: How to Prevent it," Boston Medical and Surgical Journal, March 26, 1908.

[e] "Backward Children in the Public Schools," Philadelphia (Davis), 1908, p. 7.

opthalmologists had defective vision, and of this number 12.5 per cent suffered from vision of one-half or less. The author examined personally 1,156 children and found 34 per cent with defective vision, and of this nnmber 6 per cent with vision one-half or less. A small proportion of this nnmber ouly is fitted with glasses. The rest suffer from real eye strain. The fault of this deplorable condition is divided among physicians, school-teachers, and parents. Ignorance of the existing facts, indifference, and poverty are the real factors to be dealt with.

Eye strain is the chief source of the fnnctional diseases of our citizens. It begins in early childhood and continues until senility is complete. It is bound to occur in every individual some time in his life, to a greater or less degree. It is almost the sole cause of headache, migraine, sick headache, the most frequent and habitually morbidizing of human diseases. It is the freqnent cause of gastric and digestional diseases and of nervous and mental diseases. With ocular function it conditions the origin of spinal curvature, either directly or indirectly, through the pathogenic writing posture. Lateral spinal curvatnre, the effect of visual function, becomes a new secondary sonrce of multifarious morbidities, such as neurasthenia, pelvic diseases, hysteria, etc. It has been demonstrated that 27 per cent of European school children have lateral spinal curvature at the age of 14, and I have proved that at least 70 per cent of our own 16 to 18 year old young men of the educated classes have this disease. Surprise at the fact will soon become horror at the national and social tragedy which these true figures indicate.[a]

Investigations in other cities and States[b] have shown similar results, in view of which it is a conservative statement to say that from one-half to two-thirds of our school children need medical treatment of some sort.

At least one year in each division of schooling, elementary, secondary, and collegiate, is lost to the majority of students because of unnecessary sickness or dullness caused by improper living.[c]

That physical defects are responsible for much of the backwardness of children, and for a large share of truancy and incorrigibility, is the opinion of many educators.[d] In order to correct physical abnormalities and thereby to hasten mental and moral progress in school life, a number of cities have instituted medical inspection of schools.

So far as inquiry has been able to discover, there were in the month of June, 1908, 70 cities in the United States, outside of Massachusetts, having some form of medical inspection of schools. In the State of Massachusetts 32 cities and 321 towns had systems more or less complete. It is at present impossible to compute, or even to closely conjecture, how many children these systems reach at the present time. It is entirely certain that they do not reach all of the children in the schools of those cities and towns where systems of medical inspection are actually or nominally in operation.[e]

New York City employs 150 physicians, who visit each public school once a day, shortly after 9 o'clock, to examine those children set aside by the teacher

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[a] Letter from Dr. George M. Gould, who perhaps more than any other American has emphasized the evils of eye strain.

[b] See an article by Prof. M. V. O'Shea in the World's Work, Vol. V, in which the results of extensive investigations were given. See also Dr. W. B. Drummond: "An introduction to child study," Chs. IX and X, "Report of Conference of State Sanitary Officers of New York," Buffalo, October, 1907, and various Baltimore and New York City school reports.

[c] Letter from Mrs. Ellen H. Richards.

[d] See O'Shea: "When character is formed," Popular Science Monthly, Vol. LI; Rowe: "Physical nature of the child," Chs. 9, 10, 13, 14; Scott: "Sacrifice of the eyes of school children," Popular Science Monthly, October, 1907; Gould: "The cause, nature, and consequences of eye strain," Popular Science Monthly, December, 1905; Travis: "The Young Malefactor, a Study in Youthful Degeneracy;" Swift: "Mind in the making," Chs. IV and V; Tanner: "The child," Ch. III; Kirkpatrick: "Fundamentals of child study," Ch. XVII.

[e] Letter from Dr. Luther H. Gulick.

as requiring attention. Chicago employs nearly 100 physicians to visit her public schools. In Chicago during the ten months of the school year ended June 26, 1908, the medical inspectors of schools examined 406,919 pupils.[a]

And one health officer, Doctor Chapin, of Providence, has even established a special fresh-air school for children who suffer from certain forms of tuberculosis or who come from tuberculous families. He says concerning it:

> Our fresh-air school has only been running since last January (1908), and, of course, we have no very definite results. All of the children without exception improved in health, and gained in strength, and also showed good mental progress. The cost of the school per capita is only about 50 per cent more than in the ordinary schools, and we believe that the expense is fully justified. If we had a large enough school, so that it could be graded, the cost of education would, owing to saving in fuel, probably be less than in an ordinary school.

Several States are making progress in these directions.

> Connecticut, Massachusetts, and Vermont have passed laws making examination of eyes, ears, and method of breathing of the public scholars compulsory, while New York, Illinois, and some other States of the Middle West depend upon the voluntary cooperation of the teachers in making this examination. It would seem, however, that whether it remains voluntary or becomes compulsory, its success will be greatly enhanced if women who are conducting teachers' institutions in the department of education devote a half hour or an hour to the exposition of the necessity of such an examination and also in explaining the method in detail and the method of tabulating the results, so that the teachers may be familiar with the tests, etc., when they have to make them. With the great power lodged in the department of education in this State, it would seem justifiable to make this compulsory.[b]

We in this country should profit by the experience of older countries in respect to school hygiene. Switzerland has led the nations in its concern for the physical welfare of its children. A number of other European countries are beginning to imitate Switzerland in attaching supreme importance to health and hygiene in educational work. There is now before the English Parliament a bill the purpose of which is to establish a national system of medical inspection of schools, and it seems probable that this measure will be enacted into law.

It is generally recognized by physicians and educators to-day that many children in the schools are being seriously injured through nervous overstrain.[c] Throughout the world there is a developing conviction that one of the most important duties of society is to determine how education may be carried on without depriving children of their health. It is probable that we are not requiring too much work of our pupils, but they are not accomplishing their tasks economically in respect to the expenditure of nervous energy. Some experiments made at home and abroad seem to indicate that children could accomplish as much intellectually, with far less dissipation of nervous energy, if they were in the schoolroom about one-half the time which they now spend there. German educators and physicians are convinced that a fundamental reform in this respect is needed. In fact, among school children we are learning the same lesson as

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[a] A. L. Craig, "Report of the standing committee on contagious, infections, and hereditary diseases," Associated Fraternities of America, August 1, 1908.

[b] Twenty-eighth Annual Report State Board of Health of New York, 1908.

[c] See Dr. Adolph Meyer, "What do Histories of Cases of Insanity Teach Us Concerning Preventive Mental Hygiene during the Years of School Life?" The Physchologic Clinic, June 15, 1908.

among factory employees, viz, that high pressure and long hours are not economy but waste of time.

In American cities one of the greatest needs to-day, in order to conserve the vitality of children, is the establishment of playgrounds easily accessible to all the children of any community. We are told that the physical and the mental are inseparably joined together, and if the one is defective the other will suffer through sympathy. Now it appears to be impossible to develop the child physically in any way so effectively as through active play. Formal gymnastics can accomplish relatively little. The child must have some end to attain that arouses its enthusiasm, and that demands agility and strength and endurance; then its whole bodily mechanism will work together in harmony to achieve this end. And this is what a physical training seeks to accomplish—to make the body a fit instrument for the mind. Let the child have some place where it may not only play games freely without fear of the police but where it may run and jump and climb and swing and work in sand and throw stones and wrestle, and it will not fail to make the most out of the body nature has given it as a housing for a sound and efficient mind.

Even if playgrounds were of no value in social development, they would still be of inestimable service in keeping children out of crime and lessening expense for police, courts, reformatories, hospitals, and prisons—a point which was strongly emphasized in the report of 1897 of the committee on small parks in New York. If a boy's energies are not used up in wholesome activity they will surely find expression in illegitimate conduct. The boy will prey upon the institutions which prevent him from living a natural life. "The greatest enemy to the police is the boy," said a high Philadelphia official recently. Go to the storekeeper, to the shopkeeper, to the housekeeper, and you will hear the same story. The boys steal, break windows, insult, afflict, upset one thing and another, and would do almost anything they hear or see in order to satisfy that burning instinct for play. "These beginnings of vice and crime were the only outlets they have had for the powers with which nature has endowed them. These practices were their only or chief amusement, and thus happiness to them became synonymous with vice and fiendish delight in evil doing."[a]

But in studying the life on the playgrounds the same official sees that they lay the foundations for—

strong, manly, bright, and happy lives, rescued from the evil habits and tendencies that produce misery and wretchedness. * * * Through their play in this manner the young are taught how to live together, how to respect each other's rights, how to be kind, gentle, pure, in language as well as in conduct. The boy's mouth is not defiled by tobacco, liquor, or profane language. The disrespectful and vulgar treatment which young boys and girls inflict upon each other in the street is done away with. The playground influences are brought into the home, where the younger brothers and sisters treat each other much differently from the way they do now; or, to put it the other way, the influences of the home, the school, and of the church are thus extended outside over the whole life of the child.[a]

To playgrounds may be joined school gardens, which Superintendent Maxwell in New York has shown would not be expensive,

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[a] Secretary of Philadelphia Culture Extension League.

or open-air gymnasia, or any other equipment that will give children the opportunity to develop physically.

Physical education is a part of the training in many public schools and in a still greater number of private schools, but there is room for improvement. After pointing out, in a recent article on physical deterioration, that Germany, France, and Austria have improved their physical development by compulsory physical training in all civil and military educational institutions, the Rev. Percy Stickney Grant advocates the instalment in the United States of:

> 1. An effective system of physical education as a recognized part of all public-school systems. By "effective" I mean one that does for a boy, as far as his physique is susceptible, what army setting-up exercises do for a recruit.
> 2. Athletic exercises in schools, using gymnasia, baths, etc.
> 3. Open-air exercises and sports under efficient supervision.
> 4. Summer camps free of cost, and compulsory attendance for boys of school age.[a]

The study of hygiene and physiology has been part of the public school curriculum for some time, but has been regarded by physiologists as a somewhat partisan and unscientific treatment of the physiological effects of alcohol and tobacco. It should be recognized, however, that it has had a salutary effect and has given school children a better idea of what alcohol means than the most of them had before.[b] Local topics of sanitation may well be taken up, as in New Haven last year when the interest of all the city school children was enlisted in behalf of a "clean city." Doctor Stiles, of the Public Health and Marine-Hospital Service, has proposed an annual "health week" in the public schools, and this proposal has found favor in several States. In Georgia Chancellor Barrow has proposed an annual "health day" in the public schools of that State, which would be devoted to lectures on sanitation, on the dangers to be expected from unscreened windows, and on the character of the hook-worm disease, with suggestions as to its elimination.

> At present the schools look to parents to instruct their children in the supposedly simple matters of regulating eating and drinking, exercise, habits of work, and sexual habits, while the parents vaguely hope (if they think about such matters) to be relieved of these embarrassing duties through the schools. The truth is that neither parents nor schools are to-day able to give this much-needed sort of education. The remedy must be provided by the schools, which in their eagerness to impart conventionalized facts are now quite blind to some of the most pressing needs of their pupils. Through the schools and universities (or other appropriate organizations) the parents of the future must be educated both as to the facts and the moral aspects of bodily hygiene. And it seems not unreasonable to hope that some of the lessons now learned only by bitter experience, after much that is best in life has been sacrificed to ignorance and uncurbed impulse, will be assimilated sufficiently early in life to mitigate materially the lot of a not inconsiderable part of mankind. I beleve the lengthening of the span of human life to be among the attainable results of such teaching. Is it not likely that as men grow wiser an increasing number will deliberately strive so as to regulate their lives as to improve the expectation of crowning well-spent days with the peculiarly fine satisfaction of old age?[c]

If the school building were a model of ventilation, lighting, and sanitation, it would not only conserve the health of the school chil-

[a] Rev. P. S. Grant, North American Review, February 1, 1907.

[b] See Dr. Helen Putnam, "Studies of the Present Teaching of Hygiene, Through Domestic Science and through Nature Study," American Academy Medicine (Easton, Pa.), 1905.

[c] C. A. Herter, M. D., "The Common Bacterial Infections of the Digestive Tract," New York (Macmillan), 1907, p. 351.

dren, but also serve as an object lesson for hygienic instruction. In the same way cooking and domestic science classes could be made to serve the double purpose of providing a hygienic noon meal and training the school children, especially the older girls, in the principles and practice of this vitally important subject. Our schools are suffering from the conventional idea that education comes from books. Education is preparation for life, and should make use of every efficient method and element, manual training, athletics, observational nature study, laboratory experiments, and object lessons of all sorts, as well as book instruction.

SECTION 5.—*Voluntary and business organizations.*

A host of distinctly voluntary associations are working for the improvement of hygienic conditions. Among them may be mentioned the National Association for the Study and Prevention of Tuberculosis, the Society for Sanitary and Moral Prophylaxis, the Chicago Society of Social Hygiene, the Connecticut Society of Mental Hygiene, the national and state child labor committees, the Congress on School Hygiene, the Children's Aid societies, the Sunshine societies, the American Playground Association, the Visiting Nurses' Association, the Red Cross Society, the American Association for Labor Legislation, the numerous temperance organizations, university settlements, institutional churches, Young Men's Christian Association and kindred associations, the American Physical Education Society, the Boston Health Education League, and the American Health League established by the Committee of One Hundred on National Health.

That various large bodies of men are waking to the importance of health study is shown by the appointment, at the last annual meeting of the Associated Fraternities of America, of a committee on infectious, contagious, and hereditary diseases, with Doctor Craig, of Chicago, as chairman. Labor unions may well follow this example and provide for the education of their members in the subject of hygiene. This could be effectively combined with their endeavors to shorten the hours of labor. Especially unhygienic is the arrangement by which a man has no interest in his work beyond that represented by his pay envelope. This fact has been recognized by some farsighted employers of labor, with the result that they now employ social secretaries or "welfare workers" to look after the general well-being of employees. A social secretary watches over the health, comfort, and happiness of the force during working hours, establishes lunch rooms, rest rooms, mutual aid associations, thrift funds, and penny provident banks. Employers, as a rule, become eager for practical suggestions and expert advice on the well-being of their employees as soon as the matter is called to their attention. Doctor Favill, president of the Chicago Tuberculosis Institute, after speaking before the Commercial Club, was urged by 15 or 20 of the large employers present to undertake investigation of their establishments and to make recommendations.

Dr. Hubert Higgins describes an interesting experiment carried out in a mill near Paris, where there were employed 44 men and 75 women and children. A medical officer was employed to supervise the sanitary appliances and regulations and to give careful instruction and explanations. He held practical instruction classes with the mothers, lecturing on diet and cooking, cleanliness, the way to take body temperatures, and how to look at the children's throats.

This experiment was entirely successful, though the doctor lived in Paris. There was not a single death in three years. There were one or two cases of scarlet fever and diphtheria, that were promptly and effectively isolated. This experiment was not philanthropic, but financial, the employer realizing that he had better value in work from healthy hands.[a]

A few factories now use or permit the use of a reader to read to their employees, where the manual nature of their work is such as not to be hindered by listening to a story. Others use a piano and have their employees march in and out to music. The curious physiological relations between rhythm and work are now being observed by physiologists. Laboratory tests with ergometers seem to show that more work can be done under the stimulus of rhythm. Soldiers and sailors have for ages made use of music and rhythm, and it would not be beyond the range of possibility if the factory system should in some cases find more use for it than at present.[b]

Unconsciously, business corporations have also made changes which tend to improve the sanitary conditions under which their employees work. In a large telephone exchange in Chicago the perfect working of the apparatus was much hampered by dust, so that insulation was seriously affected. To obviate this condition an expensive system was put into operation, by which the air was washed and pumped into the rooms under ideal conditions. What the company aimed at was the perfect health of its apparatus, but it gained in addition a decided improvement in the health of its employees.[c]

Another similar organization, the New England Telephone and Telegraph Company, at Cambridge, Mass., ventilated its offices during the winter of 1907–8 with unusual care, with the result that the number of days of work lost by its 60 female employees was cut in half.

The need of industrial efficiency is driving business men to demand temperance or even total abstinance among their employees. This is one of the most powerful motives to-day working against the abuse of alcohol. In the South employers and the public see that negroes who drink are inefficient and dangerous. Railway officers and the traveling public realize that public safety requires sober locomotive engineers and firemen. Even drinking among sailors is being discountenanced. Doctor Grenfell, the missionary among the Labrador fishermen, says: "Why don't I want to see liquor used at sea? Because when I go down for a watch below, I want to feel that the man at the wheel sees only one light when there is only one light to see."

Among semipublic institutions with power to exercise prodigious influence in improving the public health are the life insurance companies. Just as fire insurance companies make efforts to decrease the risk of fire, so life insurance companies might well join in public health movements to effect a reduction in the human death rate.

While the financial motive is sordid, it should be utilized because of its tremendous power. The insurance companies to-day represent

[a] Hubert Higgins, "Humaniculture," New York (Stokes), 1906, pp. 209–211.
[b] See Karl Bücher, "Arbeit and Rythmus," Leipzig, 1902.
[c] See Outlook, May 26, 1906.

an invested capital of over $3,000,000,000. An actuary recently remarked to me, in connection with this subject, that they could without feeling it contribute great sums annually to the preservation of public health. When insurance companies were established, the old dictum that human vitality followed a fixed law served probably to exclude the idea of preventing death claims rather than paying for them. Now that we are learning the preventability of disease, the time must come when insurance companies will take an active part in the fight. Even a single company would probably make a good investment if it sought to educate its own "risks." But a far more effective method would be a combination of all companies to improve public health through the enactment of public legislation—by Congress, state legislatures, municipal governments, and in numberless other ways.[a]

Among some official agencies meant to promote the social welfare are two recent commissions appointed by the President—the Homes Commission, of 1907, appointed for the purpose of studying the housing conditions in the District of Columbia, and the Commission on Country Life, appointed to study the daily life of the farmer. Farm sanitation will be especially considered.

Finally, there is a public yet voluntary agent in the progress of hygiene that must not be overlooked, namely, the modern periodical. Not only do the daily papers devote much attention to questions of health and hygienic reform, but the popular magazines have taken up the fight against disease, and are educating the popular mind, more surely than is realized, concerning the natural and normal way of life. It is necessary to add, however, that these same periodicals often nullify the benefits derivable from their reading matter by printing the most harmful of patent medicine, quack, drug, and alcoholic advertisements. Public odium should attach to newspapers and magazines that advertise hurtful nostrums. It is impossible to estimate the harm wrought to the public health each year through such advertising.[b]

The daily papers are especially culpable in this regard, but weeklies and monthlies are not wholly clear of the taint. When a newspaper's advertising space is once bought by quacks or nostrum sellers, its news columns become closed at once to matter considered objectionable by such advertisers. Frequently news items reflecting directly or indirectly on quackery are suppressed. Notable examples of publications that have taken strong ground against such advertising are Collier's Weekly, The Outlook, The Ladies' Home Journal, and a few—a very few—daily papers.

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[a] Since the above was written the Committee of One Hundred on National Health has urged this matter before the Association of Life Insurance Presidents, which body has appointed a committee to draw up plans. Also the Metropolitan Life Insurance Company has organized a bureau of cooperation and information to aid in distributing information to policy holders of the "industrial" class.

[b] For further discussion of this topic see a pamphlet by Samuel H. Adams on "The Great American Fraud," reprinted by the American Medical Association from a series originally appearing in Collier's Weekly, and "A Century's Criminal Alliance between Quacks and Some Newspapers," by Champe S. Andrews, Publications of the Committee of One Hundred, 1907.

CHAPTER IX.—*Conservation through personal hygiene.*

SECTION 1.—*Its importance.*

Following public and semipublic hygiene, we arrive at what is in many respects the most important subject of all, personal hygiene. It is quite true that the individual is often at the mercy of unclean streets, bad drainage, impure water and food, and other shortcomings of public and semipublic hygiene. On the other hand, his own personal interest is necessary in order to form the public opinion which alone can result in effective public and semipublic hygiene, while that interest is still more necessary to make such hygiene apply directly to his own person. Clean streets are of use only as they make the air breathed purer, but they are of little avail to the household which does not ventilate its rooms or which keeps them in a state of filth. The milk supply of a city may be ideal, but all the pains to make it so will be set at naught if the individual consumer allows the milk to be contaminated after it is delivered. The labeling of foods and drugs will not prevent self-poisoning through alcohol, nor will the elimination of preservatives from foodstuffs and the enforcement of sanitation in their manufacture be of avail if in their preparation for the table they are subjected to disease and dirt. Thus at every point of hygienic progress, there must be individual cooperation with public efforts.

When, contrariwise, health organizations and officials are inefficient, the individual may, in spite of these difficulties, often maintain good health. In New York a woman who was the occupant of a tenement overcame tuberculosis by sitting daily on her fire escape. The air was not the best, but it was much better than indoors. Similar results have been obtained by workmen in Brockton shoe factories, who, in spite of insanitary working places, and without cessation of work, conquered tuberculosis by sleeping on the roofs of their houses at night.

Observation shows that many, possibly most, of the world's most vital men and women have virtually made over their constitutions from weakness to strength. Cornaro, the famous nonogenarian, Kant, and Humboldt are cases typical in different fields of achievement. Cornaro, a Venetian nobleman born about the middle of the fifteenth century and given up to die at the age of 37, foreswore all unhygienic habits and began to live "the temperate life," his abstemiousness applying especially to food. His age at death is variously estimated, but he lived to be at least 97. When over 90 he wrote a treatise on longevity, laying down as the chief rules of a normal life, care in eating and drinking, and the avoidance of melancholy and passion.[a]

Centenarians have usually been persistent followers of some rule or rules of rational hygiene, even though unconsciously.[b]

Metchnikoff points out [c] that part of the supposed inheritance of longevity may not be inheritance, but similarity of environment, and that it very frequently happens that husband and wife both live to be

[a] See L. Cornaro, "The Art of Living Long" (English translation, Wm. F. Butler, Milwaukee), 1903.

[b] Metchnikoff, "The Prolongation of Life," p. 141.

[c] Ibid., p. 86.

over 100. This could scarcely happen by accident, but must be due to similar habits or environment.

Humboldt confessed to a fellow-student that in the first years of his childhood his tutors were doubtful whether even ordinary powers of intelligence would ever be developed in him, and that it was only in the advanced part of his boyhood that he began to show any evidence of mental vigor. As a boy he suffered from debility which not infrequently produced great prostration.[a]

Of recent examples may be mentioned a young physician who was given up to die of tuberculosis five years ago, but who to-day can run 25 miles without a rest; and Horace Fletcher, who in his 46th year was rejected for life insurance, but who later not only obtained his insurance, but proved his powers of endurance by cycling 190 miles on his 50th birthday.

And not only can weakness, if recognized early enough, be turned into strength, but strength, however great, may be dissipated in an incredibly short time.

Personal hygiene means the strengthening of our defenses against disease. Public hygiene seeks to destroy the germs before they reach our bodily defenses. These two branches of hygiene are simply the two forms of warfare, defensive and offensive. Both are of transcendent importance, but the defensive warfare is more within our power. We always have our defending garrison, the white blood corpuscles, to deliver us from our enemies.[b]

SECTION 2—*Branches of personal hygiene.*

Personal hygiene comprises hygiene of environment (air, soil, dwelling, clothing); hygiene of nutrition; and hygiene of activity.

Man is more dependent upon the atmosphere than upon any other environmental factor. His body is bathed in air and his most vital function, respiration, depends upon it. Deprived of air, he will shortly suffocate. If the air is confined and impure, his health will be affected. Ideal air should first of all be pure—i. e., free from injurious bacteria, from dust, smoke, and noxious gases. It should also conform to certain standard conditions of humidity and temperature. In this field lie the sciences of climatology and meteorology. Man learned long ago how to make himself almost independent of climatic and atmospheric conditions by the use of dwellings and clothing. These contrivances, however, while protecting him from the elements, have brought evils of their own. The great scourge of tuberculosis, for instance, is principally an indoor disease.

Intimately related to the appropriation, through the lungs, of oxygen from the atmosphere is the ingestion of food and drink through the alimentary canal. Normal health conditions demand in the case of ingested materials, as in the case of respired air, the greatest possible purity, freedom from injurious bacteria, and the absence of substances hurtful mechanically or chemically.

Finally, the ideal conditions of health require perfect balance of work, play, and sleep.

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[a] "Life of Alexander von Humboldt," by Lowenberg Ave-Lallewort and Dore, translated by Jane and Caroline Lassell, New York (Lee & Shepard), 1873, Vol. I, pp. 30–32.

[b] Metchnikoff, "The New Hygiene," p. 14.

While absolutely perfect conditions in these three branches of hygiene are unobtainable, hygienic progress consists in approaching these ideals as closely as possible.

The rules of personal hygiene are expressed in standard medical works on the subject. There is nothing novel in the brief résumé which follows. The radical changes in habits of living which are now being advocated and to some extent practiced imply nothing new. They have, for the most part, long been commonplaces of the medical profession. The knowledge is old. It is the application which is new. Medical men have long been telling their patients to get plenty of fresh air and to masticate their food. But until recently their advice has fallen on deaf ears.

SECTION 3—*The hygiene of environment.*

Air hygiene deals first of all with ventilation.[a] The importance of properly ventilating houses is so great that to secure this end the architecture of houses will have to be changed. The worst historical instances of bad ventilation are the imprisonment and virtual suffocation of 146 persons in the " Black Hole " of Calcutta and the confinement of 300 men in an underground room after the battle of Austerlitz. The evils of overcrowding come mainly from exhaled air and from the effluvia thrown off by the skin. Not only does overcrowding bring bad air, but it also increases the opportunity for infection.

The air in our houses has impurities of its own. Oil and gas vitiate it. Electric lights are hygienic in this respect. Air is never quite free from dust impurities. Aitkin estimates that country air carries 2,000 dust particles per cubic centimeter, city air 3,000,000, and inhabited rooms 30,000,000.

In a clean hospital ward, when air was agitated by dry sweeping, the number of colonies of bacteria collected on a given exposure rose from 26 to 532, showing the effect of ordinary broom sweeping. The broom is now being replaced by the carpet sweeper, and the carpet sweeper in turn by the vacuum cleaner. Each step represents progress in the elimination of dust. The removable rug is in this regard an improvement over the carpet.

Air may even be poisoned by the chemicals contained in wall paper or in the plaster of a brick and mortar dwelling.

The one place where the individual has more control over the air he breathes than anywhere else is his sleeping room. He may be powerless to control the air in his place of work, or even in the rooms where he lives during the day. But, except where he shares a bedroom with others who are averse to modern ideas of ventilation, he can largely control the air supply during sleep, and this means during one-third of his whole time. He can open wide his windows and in many cases arrange actually to sleep out of doors. The growing practice of sleeping out of doors is one of the most significant signs of the times. Only those who have tried it realize the benefits. The air supply in public places would be under the control of individuals, if organized in protest; and our churches, theaters, public halls, railway coaches, and railway sleepers would be properly ventilated if the

[a] See Richards and Woodman, "Air, Water, and Food," New York (Wiley), 1904; also Carpenter, " Heating and Ventilating Buildings," New York (Wiley), 1905; Sykes, " Public Health and Housing " London (King), 1901, 216 pp.

public demanded improvement. Such a "score card" as Prof. John R. Commons has devised for measuring the relation of housing conditions to an ideal standard might well be used in measuring the health utility of public places.

The windows of living and work rooms may be opened in summer and somewhat in winter, provided a window board is used, to deflect the cold air upward from the sill. It then does not form a cold stratum on the floor, but mixes evenly with the air of the room. This simple device would go far to solve the question of winter shut-ins and their ailments. In many cities sleeping balconies are not uncommon among the dwelling houses.

The many benefits from a pure air supply are only beginning to be realized. For instance, as long as "the outdoor life" is lived a cold is almost impossible. Army officers have noted that as long as the men are on the march and sleep outdoors they hardly ever have colds, but that they become troubled with these as soon as they get indoors. Franklin, a century ago, knew these facts, though few of the present generation are acquainted with them. He believed "that people who live in the forest, in open barns, or with open windows, do not catch cold, and that the disease called 'a cold' is generally caused by impure air, lack of exercise, or from overeating." He came to the conclusion that influenzas and colds are contagious—a doctrine which, a century and a half later, was proved, through the advance of bacteriological science, to be sound. The following sentence exhibits remarkable insight, considering the state of medical art at that time: "I have long been satisfied from observation that besides the general colds now termed 'influenzas' (which may possibly spread by contagion, as well as by a particular quality of the air), people often catch cold from one another when shut up together in close rooms and coaches, and when sitting near and conversing so as to breathe in each other's transpiration; the disorder being in a certain state." In the light of present knowledge what a cautious and exact statement is that.[a]

John Muir, the geologist and naturalist, says that he finds home the most dangerous place he can visit.

> As long as I camp out in the mountains without tents or blankets I get along very well, but the minute I get into a house and have a warm bed and begin to live on fine food, I get into a draft, and the first thing I know I am coughing and sneezing and threatened with pneumonia, and am altogether miserable.

Atmospheric evils come from improper ventilation, and affect either the respiratory organs of the body or the skin. It has been supposed until recently that the presence of carbon dioxid gas in vitiated air was the chief evil caused by such air. Impure air will affect the lungs harmfully, but not till the amount of carbon dioxid contained is very large. Guinea pigs, on which the effects of bad air were observed, were not seriously affected by the carbon dioxid till it amounted to 14 per cent of the volume of the air. Flügge and others have found that the evil of close atmospheres is largely a result of elevated temperature, humidity, and absence of air currents. Tests were made on men who sat in impure air, but breathed pure air through tubes, and they presented all the symptoms usually resulting from bad ventilation.

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[a] From "Benjamin Franklin as Printer and Philosopher," address of President Charles W. Eliot before American Philosophical Association, April 20, 1906.

Air baths have been shown to be as important for bodily health as water baths. For this purpose porous clothing should be worn and no more of it than is needful. Impervious cloth and rubber are probably injurious as clothing. Loosely woven worsteds, or linen and cotton mesh are best adapted to let the air play on the skin. Clothing, to be hygienic, should not constrict the body. Tight shoes, and especially tight corsets, are distinctly injurious, and the injury to mothers from the latter may be felt by the next generation. Another insanitary feature in clothes is the trailing skirt, which drags indoors the sputum of consumptives and germ-laden dirt from the sidewalk.

Closely connected with air and ventilation is light. The benefit of sunshine in killing germs and improving bodily vigor in every way is too well known to need more than mention. Tuberculosis and other germs thrive only in dark, damp, ill-ventilated places.

Light has its most important bearing on the human health through the sense of sight. Its relation to eye strain has been discussed elsewhere. Headaches, backaches, indigestion, hysteria, and epilepsy are often aided by glasses.

SECTION 4.—*The hygiene of nutrition.*

A primary necessity for hygienic living is good drinking water. The modern man of means insists upon good water, and, as a result, the traveling public is now able to get first-class water in cars, hotels, and other public places. The improvement was brought about by the appreciation by the consumer of the danger of drinking impure water. It is the consumer who has it in his power to bring about the necessary reforms in public hygiene. When he really values hygienic environment producers will supply it. Professor Sumner has told us that persons in the middle ages sometimes drank out of their castle moats, which contained sewage. Even in New York to-day the roof tanks are sometimes used as baths or laundries; and they accumulate dust and flies very rapidly. Only a few years ago the aldermen in a prominent western town laughed out of court a physician who called their attention to dangers which were real, but which they believed imaginary, from a polluted water supply.

The scientific study of diet has only just begun and few authoritative results can yet be stated. To avoid a lengthy review of controversial literature it seems best to pass the subject over rapidly, referring the reader for further information to some of the principal books on the subject.

We have already seen the surprising improvement in endurance which followed the adoption of thorough mastication in place of the ordinary food bolting. Mr. Gladstone used to be noted for his care in slowly masticating his food, and latterly Mr. Horace Fletcher has aroused the interest of the public in the subject in Europe and America.[a] He has also stimulated a large number of physiologists to study the subject of mastication, the protein ration, and their relation to strength and endurance.

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[a] See Horace Fletcher, "The A, B–Z of our Own Nutrition," New York (Stokes), 1903; Dr. Hubert Higgins, "Humaniculture," New York (Stokes), 1906; and Irving Fisher, "The Effect of Diet on Eudurance," publications of Yale University, Transactious of the Connecticut Academy of Arts and Scieuces, 1907.

A great deal has been written as to what foods are best. There exist various dietetic cults, such as vegetarians and fruitarians, raw-food advocates, etc. The question of what foods are ideally best is too large a one to be entered upon here. The evidence seems to point to a general conclusion that no hard-and-fast rule of exclusion is advisable, and that the value of different foods varies with the individual and with his activity, locality, physical condition, etc. His own instinct, restored and educated by avoiding the pernicious habit of food bolting, may be made a truer guide than the wisest physician or physiologist. The same rule applies to the amount of food to be eaten, as well as to the proportions of protein, fat, carbohydrates,[a] and mineral salts. Food bolting often leads to overeating.

It should be noted that the conclusions of Chittenden and others are not in favor of a vegetarian régime, but of a low protein régime, whether vegetarian, lacto-vegetarian, or with flesh foods in moderation. The main point is moderation of the foods highest in protein, such as the whites of eggs and meats (especially lean meats).

It would seem that the safest course for the average man is to follow the appetite, simply guiding it toward a low protein diet by thorough mastication, and by giving the benefit of the doubt to foods low in protein. A reduction in the use of meat will increase, and probably cheapen, our national food supply. The raising of cattle requires much more land than the raising of cereals, fruits, nuts, and vegetables yielding the same amount of food value. As this will be a most important economic problem during the next hundred years, the question of the character of our food supply should be most carefully considered in the study of the conservation of natural resources. It is interesting to note, in this connection, that during the last century the consumption of flesh foods in the United States has considerably decreased.[b]

The subject of auto-intoxication as a consequence of excessive protein has already been mentioned.[c] To avoid auto-intoxication the putrefactive bacteria may be neutralized by lactic bacilli, such as are contained in sour milk. Another preventive is regular attention to thorough evacuation.

Diseased foods are, needless to say, dangerous. Oysters are often planted in waters polluted with sewage, with the result that epidemics of typhoid fever have been traced to their consumption.

The housewife must be the guardian of the family in these respects, and in the cooking, preparation, and arranging of food generally. These now constitute "domestic science," which is justly winning recognition as one of the most potent of all hygienic agencies. When

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[a] For a short method of measuring these magnitudes, see Irving Fisher, "A New Method of Indicating Food Values," American Journal of Physiology, Vol. XV, No. V, April 2, 1906; and for its practical application see "A Graphic Method in Practical Dietetics," Journal American Medical Association, Vol. XLVIII, April 20, 1907. See also, "Statistics of Diet in Consumptive Sanatoria," American Journal Medical Sciences, September, 1906.

[b] See G. K. Holmes, "Meat Supply and Surplus," Bureau of Statistics, Department of Agriculture, Bulletin 55, 1907, p. 47. Mr. Holmes finds that the consumption of dressed meat per capita in the United States decreased between 1840 and 1900, 40 per cent, and betweeu 1890 and 1900, 25 per cent.

[c] Supra, Chap. V. See also Herter's "Common Infection of the Digestive Tract."

the kitchen becomes a scientifically conducted laboratory we shall have the basis of a sound "home economics."

SECTION 5.—*Drug habits.*

It would scarcely be an exaggeration to say that the first rule of hygiene is to avoid poisons. Poisons may be generated within us or ingested from without.

Drug habits take numerous forms, and they are more prevalent than most persons realize. The commonest form of intoxication is alcoholic.[a] It is interesting to observe the change which has come about in the attitude of scientists toward alcohol. From having enjoyed a high place in materia medica, it is in danger of being completely discredited.[b] So far as its habitual use is concerned the only question which remains in debate is whether in minute quantities it may be innocuous or even beneficial. In any except minute quantities it has been shown to be injurious.

It lowers the resistance of the white corpuscles, which are the natural defenders of the body. Although the phagocytes belong to the most resistant elements of our body, yet it is not safe to count on their insensibility toward poisons. It is well known that persons who indulge too freely in alcohol show far less resistance to infectious diseases than abstemious individuals.[c]

Here is the gravest indictment that may be brought against the abuse of alcohol. It is not, however, the only one. The relation of drinking to insanity,[d] peripheral neuritis, Bright's disease, cirrhosis of the liver, inflammation of the stomach, arterioschlerosis (a most common cause of apoplexy),[e] tuberculosis;[f] to crime in all its forms,[g] and to all the possibilities incident to the hereditary transmission of a weakened organism[h] has been pointed out. If personal hygiene is a duty, it is the duty of every man to recognize the danger from alcohol to himself and to his progeny yet unborn. Instead of copying the habits of others, he may consider the responsibility of causing others to copy his.

A subcommittee of the Committee of Fifty for the investigation of the liquor problem published in 1899 a volume on the economic

[a] For a discussion of the physiological effects of alcohol, see Physiological Aspects of the Liquor Problem, investigations made under the direction of W. O. Atwater, John S. Billings, H. P. Bowditch, R. H. Chittenden, and W. H. Welch, subcommittee of the Committee of Fifty; New York, Houghton & Mifflin, 1903, 2 vols.; and The Liquor Problem, a Summary of Investigations Conducted by the Committee of Fifty, 1893–1903, by John S. Billings, Charles W. Eliot, Henry W. Farnam, Jacob L. Greene, and Francis G. Peabody, 1905.

[b] The rôle of alcohol as a predisposing cause of disease has already been noted. It has long been known that drunkards have a very slim chance of recovery when attacked by pneumonia, and it is noted also that the mortality among moderate drinkers is higher than among total abstainers. This fact has long been known to life-insurance companies as holding good for many diseases other than pneumonia. Osler: Modern Medicine, Vol. II, p. 628.

[c] Metchnikoff: The New Hygiene, p. 25.

[d] See "Twenty-sixth Annual Report of Massachusetts Bureau of Labor," 1905.

[e] Ditman, loc. cit., p. 47.

[f] See John Huber, M. D., "Predisposition to tuberculosis," The Medical News, December 26, 1903, p. 12. Also reports of Phipps Institute, Philadelphia.

[g] See Boies's various works, the "Reports of the Committee of Fifty," and Report of the Massachusetts Bureau of Labor Statistics, 1895.

[h] See Henry Smith Williams, M. D., "Alcohol and the Individual," McClure's Magazine, October, 1908, pp. 704–712.

aspects of the problem. The investigation covered a period of about three years and was carried on under the general direction of Prof. Henry W. Farnam, of Yale University. The general conclusions of this investigation were that of the poverty which came under the notice of the charity organization societies about 25 per cent could be traced directly or indirectly to the use of liquor; of the poverty found in almshouses, about 37 per cent. In the investigation of crime, the conclusion was reached that liquor was a first cause in 31 per cent of the criminals studied, and that it entered in as a cause, directly or indirectly, in 50 per cent.

The investigation made by the Massachusetts bureau of statistics of labor in 1895 indicated the following percentages due to alcoholism:

	Per cent.
Crime	84.41
Pauperism	48
Insanity	35

Several English life-insurance companies—the Sceptre, the United Kingdom, and General Provident and others—have found by their statistics, running over forty years, that abstainers have a death rate about 23 per cent lower than nonabstainers.[a] Since the figures of the Mutual Life Insurance Company of New York[b] give the same advantage to American abstainers (23 per cent lower death rate), it seems fair to take the available computations of the English life insurance companies as a basis for estimating the saving of life that would result in the United States if individuals should decide to give up the use of alcohol. It should be remembered, however, that the favorable figure of total abstainers is partly due to the fact that as a class they practice personal hygiene in all its forms.

A basis for computing the sickness that might be saved by total abstinence is furnished by comparison between the sick rates of abstaining and nonabstaining societies, made by Mr. H. Dillon Gouge, public actuary of South Australia, in 1892. He found that the average weeks of sickness in three societies of abstainers was 1.248; in three societies of nonabstainers the average weeks of sickness was 2.317 (lacking only one-sixth of being twice as much).

Absinthe in France has become almost as clearly a cause of national degeneration as opium in China. Fortunately for our own country there exists here a more determined effort than in most, if not all other nations, to be rid of alcoholism. The movement has been formidable enough to arouse anxiety among those whose capital is invested in breweries, distilleries, and saloons. The movement reaches its maximum momentum in the west and the south of the United States. It is significant of the rapid change of sentiment in regard to the liquor question that physiologists, physicians, educators, and publicists are now becoming so thoroughly impressed with the importance of suppressing the evils of alcohol.

The younger members of the Kaiser's family in Germany are opposed to the German habits in regard to the use of alcohol, and the son of the Kaiser chose for his university one where there was less

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[a] Letter from Miss C. F. Stoddard, secretary of the Scientific Temperance Federation.

[b] "Effect of Total Abstinence on the Death Rate," by Joel G. Van Cise, actuary of the Equitable Life Assurance Company of the United States.

drinking than at other universities. President Eliot, of Harvard University, has recently taken a strong position against the use of alcohol, even "in moderation."

Another common, though less injurious, source of self-poisoning is tobacco, which is known to stunt the growth of the young, to lead to sluggishness and weakened hearts ("tobacco hearts"), and to cause dyspepsia and neurasthenia.

Snuff taking has almost disappeared as a habit in this country. Chewing tobacco is still common, though no longer defended by hygienists. "Inhaling" is more common, though also usually condemned on grounds of health. Smoking shows no signs, as yet, of decreasing. In moderation it may not be injurious. There are no definite proofs on either side. But smokers are seldom moderate.

Doctor Seaver, of the Yale Gymnasium, found that of the 187 men in the class of 1891, Yale College, those not using tobacco during the college course had gained over the users of tobacco in weight 32 per cent, in height 29 per cent, in growth of chest 19 per cent, and in lung capacity 66 per cent.[a]

Similar returns for the Amherst graduating class of 1891 showed a gain by the nonusers of tobacco of 24 per cent in weight, of 37 per cent in height, and of 42 per cent in growth of chest. In lung capacity the tobacco users had lost 2 cubic inches of air space, while the nonusers had gained 6⅓ cubic inches.

The somewhat injurious effect of tea, coffee, and condiments, though less than many other evils, should be included in any list of the imperfections in respect to hygiene of existing habits of life.

SECTION 6.—*Activity hygiene.*

Only a generation ago there were scarcely any gymnasia in this country, but to-day the importance of regular exercise and bathing is recognized by everyone. This is far from saying, however, that this important method of conserving our vital resources has more than begun to be exploited.

First, the bath for the well-to-do, and, latterly, the public baths for the poor, have given all an opportunity to obtain the cleansing and healing agency of water. And in recent years the application of baths has become a science.[b]

Baths may be used as social agents. Judge Ben. B. Lindsey, of the Denver juvenile court, insists that every child must take a bath before appearing in the court room. Neutral baths, i. e., baths regu-

[a] Doctor Anderson, of the Yale Gymnasium, finds similar results. He also points out a statistical pitfall into which some investigators have fallen. This is the common statistical fallacy of selection. There are two great groups of college sudents, roughly distinguished as athletes and scholarship men. (See Doctor Sargent, "Physique of scholars, athletes, and the average student," Popular Science Monthly, September, 1908.) Smoking is more common in the former group. They are not athletes because they smoke, but smoke because they are athletes. The raw figures of smokers and nonsmokers usually show that the smokers have better physical development, but if we compare the smoking athletes with the nonsmoking athletes and the smoking scholarship men with the nonsmoking scholarship men the results are quite different. For similar statistical fallacies, due to failure to subgroup properly, see Mayo-Smith, "Statistics and Sociology," Macmillan, 1895.

[b] See J. H. Kellogg, M. D., "Rational Hydrotherapy," Philadelphia, 1904.

lated to the temperature of the body, have been found valuable in relaxing the nerves of the body, and even in the treatment of mental disease.

As to exercise, a healthy organism must call into play every function daily, both mental and physical. One of the evils of the division of labor which civilization has brought is that the sedentary worker does not have enough physical exercise, but too much mental exercise, while the situation is just the opposite in the case of the workingman.

A well-known physical director, now nearly 50 years old, writes me that he has this year taken up systematic physical training, which he has neglected for several years because of pressure of work. As a result his weight has risen, his chest and arm girths have increased, while his waist girth has decreased, and he is conscious of decided improvement in memory and in sleep. This instance is cited as an example of the physical development possible in a man of middle age.

In its bearing on exercise, the growth of modern athletics and its effects on the physical ideals of men and women is to be welcomed. The revival of the Olympian games and the spread of popular participation in such outdoor sports as golf, tennis, boating, and horseback riding have all had their share in building up a new health ideal. Thus we are getting away from the mediæval idea of mortification of the flesh and approaching more closely the Greek conception of a beautiful body as the covering for a beautiful soul. The Greeks lifted their sports to a higher level than ours by surrounding them with imagination and making them a training in æsthetics as well as in physical excellence.[a] The American idea is at present too closely connected with mere winning, and not enough with development. In the past the physical athlete has been too much associated with the pugilist, and has been looked down upon as having merely brute strength. The intellectual type, on the other hand, has been content wholly to neglect bodily development.

In the last three years considerable evidence has accumulated to show that the sitting posture of the sedentary man tends sooner or later to produce nervous prostration, and that the ordinary chair invites to this effect by producing a bent attitude, both in the forward direction and in the shoulders. The effect of the former is to tax the splanchnic nerves and congest the portal circulation. The splanchnic area, which is enormous, is a sort of overflow tank for the blood. If the muscles of this area are allowed to relax through improper position in standing or sitting, the result is the stagnation of the blood in the abdomen, and this in turn results in a vicious circle of evil effects. Since much of our life is spent in chairs, this fact is of no small importance. Improperly made school chairs and unhygienic habits of sitting in them may start off millions of young lives with round shoulders, curved spines, and the later effects of portal congestion.

Exercise of mind does not simply mean exercise of intellect. The emotions and the will are equally a part of a well-developed healthy man. Late in life Darwin had occasion to lament the fact that his emotional capacity had become cramped because he had exercised

[a] See G. L. Dickinson: "The Greek View of Life," New York (McClure, Phillips), 1906, pp. 131–134.

his mind in his own branch of work to the exclusion of other things. Whatever our ideas of theology or religion are, it is true that we all ought to have a spiritual sense. Some men lack this spiritual sense and are incapable of understanding the spiritual experience of others. "For toil without purposeful and occupied leisure is unfilled purpose, a process arrested midway."[a] Worry and fear are unhealthy. Hope, courage, enjoyment, and an optimistic attitude generally are healthy.[b]

The ordinary workingman works two or three hours too much every day. Nearly every man overworks himself, takes insufficient rest and recreation, and worst of all, cuts off his normal portion of sleep. Fatigue ought to be "avoided like poison," because, physiologically, it is really poison. Worry, fear, and anger also produce poisons harmful to the human body. This is suggested at least by the effect upon a nursing infant of violent paroxysms of anger, or periods of intense fear or anxiety on the part of its mother. The intense exhaustion which follows such paroxysms is another case in point.

An animal lives a much more healthy life than the average man, because an animal follows instinct, while a man to a large extent endeavors to substitute for his instincts rules which are very often false. One of the instincts constantly disregarded by man is that which finds its expression in fatigue. The ordinary man working for some one else is compelled to toil beyond the fatigue limit; and, on the other hand, if a man is in business for himself, he does the same thing of his own will. Although no one knows what sleep is, it serves, according to the best theory, to eliminate poisons and to rebuild tissue. With rest is closely associated recreation. Play practices the power of a child's mind, while contest among children develops self-control.[c] Similarly, adults are rested by play or recreation, their minds and bodies are relaxed, while their contests of mimic warfare develop their powers of will and effort.

SECTION 7.—*Sex hygiene.*

One element in personal hygiene concerns the sex relation. This can not be treated under other heads, for the sex relation is so purely a personal and individual one. From its normal utilization there is little to fear, but from the effects of illegitimate sexual practices the world suffers enormous yearly losses. It is hardly possible to have promiscuous sex relations out of wedlock without contracting one or the other of the serious venereal diseases. The best authorities report that "every prostitute is diseased some of the time and some prostitutes are diseased all of the time."

One disease, syphilis, infects the blood and therewith all parts of the body. For months after infection with this disease the indi-

[a] Simon N. Patten: "The New Basis of Civilization," New York (Macmillan), 1907, p. 158.

[b] Du Bois: "The Psychic Treatment of Nervous Disorders," New York, 1905, 465 pp. Saleeby: "Worry, the Disease of the Age," New York (Stokes), 1907. Sidis: "The Psychology of Suggestion," New York (Appleton), 1899, 386 pp. Schofield: "The Force of Mind, or the Mental Factor in Medicine," London (Churchill), 1902, 309 pp.

[c] See President G. Stanley Hall: "Play and Dancing for Adolescents," Independent, reprinted in "Mind and Body," Vol. XIV, 1907, pp. 43–48.

vidual may communicate it by a kiss as well as by cohabitation; and articles moistened by his secretions—towels, drinking glasses, pipes, etc.—may also convey the infection. While under proper treatment the disease is not always dangerous to life in the earlier years, yet the possibilities of transmitting the contagion should forbid marriage for at least three years.

The most serious results of syphilis, some authorities say, may appear years after its acquisition, when the individual has been lulled into a false sense of security by long freedom from its manifestations and considers himself cured. Many cases are practically incurable. Some are fatal in spite of treatment. It may attack any organ of the body. Among the many diseases to which it may lead are apoplexy, paralysis, insanity, and locomotor ataxia; and these often appear after the man has acquired a family that is dependent upon him for support.

The leading insurance companies refuse to insure the life of a syphilitic person for four or five years after the disease was contracted, and then only upon special terms, for their records prove that syphilis shortens life.

That the syphilitic parent may transmit the disease to his offspring is common knowledge. Some of his children are destroyed by the inherited disease before birth; others are born to a brief and sickly span of life; others attain maturity, seriously handicapped in the race of life by a burden of ill health, incapacity, and misery produced by the inherited taint, while still others escape these evil effects.[a]

Forel, in Die Sexuelle Frage, shows that even Weissman does not deny the possibility of poisoning the germ cell and so transmitting some "acquired characteristics," as in alcoholism and venereal poisoning. One of the saddest facts in both cases is that the parent may escape and the children reap the results in insanity, tendency to consumption, and prostitution.

Another disease—

Gonorrhea, while usually cured without apparent loss of health, has always serious possibilities; it kills about 1 in 200; it impairs the sexual power and fertility of a much larger number; it often produces urethral strictures, which later may cause loss of life.[a]

The persistence of gonorrhea in the deeper parts long after it is outwardly cured leads to the unsuspected communication of the disease to women with whom the individual may cohabit. Much of the surgery performed upon women has been rendered necessary by gonorrhea contracted from the husband. Should she while infected with this disease give birth to a child, the baby's eyes may be attacked by the infection, sometimes with immediate loss of sight. Probably 25 per cent[b] of the blindness of children is thus caused.

Dr. Prince A. Morrow says:

This social danger comes from frequent introductions of these diseases into marriage. The frequency of marital contamination does not admit of exact mathematical expression, as both social sentiment and professional ethics unite to cover up and conceal it. Possibly 10 per cent of men who marry infect their wives with venereal disease.

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[a] Circular No. 2, "Self-protection," Chicago Society of Social Hygiene, pp. 7–8.

[b] The average of a great many statistics shows that one-fourth of all blind persons owe their affliction to the effects of opthalmia of the new born." Chas. H. May, M. D., ophthalmic and aural surgeon, New York, Transactions of American Societies of Sanitary and Moral Prophylaxis, Vol. II, 1908.

The report of the Committee of Seven (New York) shows that in private practice nearly 30 per cent of venereally infected women were contaminated by their husbands. The report of the Committee on Sanitary and Moral Prophylaxis (Baltimore) shows that nearly 40 per cent of the infections in women seen in private practice were communicated in married life. "My own observations at the New York Hospital, extending over a period of several years, would indicate that fully 70 per cent of all women who came there for treatment of syphilis were respectable married women who had been infected by their husbands.[a]

Observation shows that gonorrhea is markedly intensified in virulence and danger to the woman in fulfilling the functions for which marriage was instituted. Pregnancy and childbearing open the way for germs. One of the most constant effects of gonorrhea in women is permanent and irremediable sterility. Fifty per cent of gonorrheally infected women become absolutely sterile, and a still larger percentage sterile after the first child is born (one-child sterility). Noeggerath found in 81 gonorrheal women 49 entirely sterile. In 80 sterile marriages Kehrer found 45 caused by inflammatory changes of gonorrheal origin. It is estimated that the husband is directly responsible for 20 to 25 per cent of sterility from his inability to procreate as the result of gonorrhea. In addition the husband, though not sterile himself, may infect his wife, rendering her sterile. The disease is ultimately responsible for about 70 to 75 per cent of all sterility in married life, which is not of choice, but of incapacity. Lier-Ascher's careful statistics place this proportion at 71.2 per cent. These figures relate to absolute sterility. The chief social danger of gonorrhea as a depopulating factor is the creation of secondary sterility, or what has been expressively termed "one-child sterility." The large percentage of marriages in which one child represents the total fecundity of the family justifies the conclusion that this sterility is in many cases not of choice, but of procreative capacity extinguished by gonorrhea.[b]

In addition, the inflammation set up in the maternal organs may render the mother a permanent invalid or compel her to submit to a mutilating operation to save her life.

Gynecologists furnish statistical evidence showing that 80 per cent of the deaths due to inflammatory diseases peculiar to women[b] and about 70 per cent[c] of all the work done by specialists for diseases of women is caused by gonorrhea.

In addition to the effect of a low protein diet on endurance, already discussed, and on general health, its relation to the sexual life should be mentioned. Experiments on this subject seem to show that excessive meat eating and excessive protein intake tend to irritate the sexual organs and to produce abnormal sexual desire just as they do

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[a] Morrow, Social Diseases and Marriage, Philadelphia (Lea), 1904.

[b] In report of special committee of the American Medical Association, 1901, Hunniston says: "Ninety per cent of inflammatory troubles of maternal organs are attributable to gonorrhea." Price says: "That in over 1,000 operations for pelvic trouble 95 per cent were attributable to this infection." Another authority gives a percentage of 75.

[c] Address of Doctor Cleveland, president of American Gynecological Society, at National Congress of American Physicians and Surgeons, Washington, 1907.

a desire for alcoholic stimulation. This fact is of importance in preventing secret vice among the young.

Thanks to the efforts of a few farsighted men like Dr. Prince A. Morrow, Prof. C. R. Henderson, and Mr. Edward Bok, these subjects are being given some of the publicity they deserve. Reticence on these subjects is justified only so far as it makes for youthful innocence. But ignorance is not innocence; on the contrary it is the surest road to guilt.

SECTION 8.—*Personal hygiene in general.*

Personal hygiene is only beginning to be generally exploited. Most persons leave their health to be attended to by physicians and health officers, just as many people leave their religion in the hands of a priest or clergyman. So far as practiced at all, personal hygiene has been confined chiefly to invalids and athletes. Even by them it is usually practiced to tide over an illness or to prepare for a contest. But it is manifest destiny that a wise economy of vitality will sooner or later be practiced. Waste of vital resources is as irrational as waste of natural resources. Neither is inexhaustible and both must be conserved. Thoughtlessness and ignorance are the reasons for the appalling waste of both now going on. Even people who do not defiantly abuse their strength by definite excesses are liable to waste it gradually. Slightly unhygienic habits grow, and their effects are doubtless cumulative. It is well known that even a so-called "ventilated house," if lived in long enough without sufficient outdoor life, may induce tuberculosis. This must be through the repetition of an infinitesimal injury produced through each respiration eighteen times a minute for twenty-four hours a day for half a lifetime.

So with the use of food preservatives. Food manufacturers have laid much emphasis on the fact that preservatives are "harmless" because used in small quantities, but Doctor Wiley has raised the question whether even very small quantities of these preservatives, if used continuously for a sufficient length of time, are not injurious. The same applies to the repetition of preservatives in a large number of different foods. If only one particular food contained a preservative, the effect would be relatively negligible; but as one food after another has become adulterated, the human stomach is made the daily receptacle of many times the "harmless" amount in any one particular food. The obstacles to hygiene which have accumulated with civilization are almost as numerous and as small as the barnacles which impede a ship. To remove them is in large part to "return to nature." Many of the inventions of which civilization boasts have had an unhygienic side. The invention of houses has made it possible for mankind to spread all over the globe, but it is responsible for tuberculosis, especially after glass was devised, which while letting in the light keeps out the air. The invention of cooking and preparing foods has widened the variety of man's diet, but has led to the decay of his teeth.[a] The invention of the alphabet and printing

[a] See Ottofy, "The Teeth of the Igorots," Dental Cosmos, July, 1908, where it is shown, statistically speaking, that the teeth of Americans are "ten times as bad as those of the Igorots," while the civilized Filipinos have teeth as bad as those of Americans.

has made possible the accumulation of knowledge, but it has produced eye strain with all its attendant evils. The invention of chairs has added to human convenience, but has led to spinal curvature and abdominal congestion. The device of a division of labor has added to wealth, but has destroyed the normal balance of mental and physical work, recreation, and rest. Similar fault may be found with clothing, especially corsets, shoes, and hats, and with numerous other contrivances. Yet it would be foolish, even if it were possible, to attempt to "return to nature" in the sense of abolishing civilization. We must not go backward, but forward. The cure for eye strain is not in disregarding the invention of reading, but in introducing the invention of glasses. The cure for tuberculosis is not in the destruction of houses, but in devices for ventilation. It is a little knowledge that is dangerous. Civilization can, with fuller knowledge, bring its own cure and make the "kingdom of man" far larger, even in respect to hygienic conditions, than "nature" people can ever dream of.

Unhygienic customs and fashions are exceedingly slow to yield, but they do yield in the end. It should be the part of intelligent men to lead in hygienic reform, not by intolerant and impatient abuse of their fellow-men, but by the quiet force of example. The intolerant and impatient reformer does incalculable harm, for he takes no account of that subtle perversity of human nature which resents his interference. Equally harmful is the man who seeks only to imitate the crowd, who condones the vices of his time and country.

But we must always bear in mind what has been called the "psychology of the crowd." Tarde, Le Bon, Baldwin, Ross, and others have shown that society is largely ruled by customs which grow out of imitation. In order that any social custom shall be changed, initiative is necessary. The upper classes should take the lead, for any reform will spread many times more quickly when the initiative comes from above than when it comes from below. Western civilization has made its marvelously rapid progress in Japan for the simple reason that the Mikado approved, and marvelously slow progress in China for the simple reason that the Empress disapproved.

We find the same principle at work in the progress of medicine. Hydrotherapy originated with a peasant and required three centuries to come into vogue. The use of sour milk, on the other hand, has been advocated only during the last two or three years, but the initiative came from Metchnikoff, one of the foremost of medical scientists. The consequence is that the so-called "sour-milk craze" has already led to great industries and affected the business of groceries, soda-water fountains, and even liquor saloons.

The change constituting hygienic reform will be brought about most rapidly by the influences on the young. If children in their homes and schools are given proper models for imitation, the public opinion which they will form may make a revolution in a single generation. Anyone who realizes the almost resistless force of the principle of imitation, especially when applied to children, will receive a new sense of the responsibility he takes in setting an example to the young. There are three classes in particular on whom the responsibility is heavy—teachers, physicians, and parents. If they wish the child to be free from the cigarette habit, they must sacrifice the cigar and pipe habit, even though it be true that cigars and pipes are not injurious to adults. They may believe this, but the children will not. The same principle applies to other and more serious infractions of the laws of health. It is probably through the love of the next generation, rather than through any selfish care for the present, that men and women now living will take the most pains to secure the best results in bringing about the change in living conditions for which every hygienist hopes.

CHAPTER X.—*Are hygienic measures eugenic?*

SECTION 1.—*Prolongation of weak lives.*

We have discussed two factors which cooperate to produce vitality, namely, heredity and hygiene; and two corresponding methods of improving vitality, namely, by utilizing a possible science of eugenics on the one hand and by utilizing the existing science of hygiene on the other. The question now arises, Are these two methods in conflict with each other? It is charged that hygiene prolongs the lives of unfit and defective classes. We have already seen that in Indiana, institutional care of the insane has prolonged the average insane lifetime by some eight years. Referring to the insane, Dr. Charles Dana says:

> For twenty-five years the explanation of this increase in statistics of insanity has been that more cases were observed and more victims kept in institutions than formerly; and this is still the explanation. It is my opinion, however, that the increase is a real one, and it is one to be expected not only from the strenuousness of modern life and increase of city population, but also, because more feeble children are nursed to maturity and more invalid adolescents are kept alive to propagate weakly constitutions or to fall victims themselves to alienation, the period of life susceptible to insanity is longer.
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> A fourth of the cases of insanity is due to so-called "moral causes:" Emotional strain, shocks, and vicious indulgences. But moral causes are not sufficieut to cause insanity if the individual has a strong constitution. Insanity is increased in part, then, because we are saving too many lives by the careful regulations of our health boards. Hence, those who are working so enthusiastically and nobly and successfully in preventing disease achieve results which carry serious responsibilities for the State.[a]

It is true that we prolong the lives of the insane and defective classes, and that they thus make a greater burden on society. We should see to it that certain of these classes are not permitted to propagate their kind. This point has been explained in Chapter VI.

It is further claimed that infant mortality is but the operation of natural selection and should not be interfered with if we are to keep up the vital power of the race. Preventive medicine has certainly prolonged the lives of infants or, at any rate, of children in general.[b] But has this weakened the race? It is pointed out that the mortality later in life has not decreased, and that in some cases it has even tended to increase. But this fact can be explained in either of two ways. One is on the hypothesis of the extension of the lives of weak

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[a] "Psychiatry in its relation to the other sciences," by Charles L. Dana, M. D., before the section on psychiatry at the International Congress of Arts and Science, at St. Louis, September, 1904. See also Janus in Modern Life, by W. M. Flinders Petri, New York (Putnam), 1907.

[b] See Edwin Graham, "Infant mortality," Journal American Medical Association, September 26, 1908; also Edward B. Phelps, "Statistical study of infant mortality," Quarterly Publications American Statistical Association, September, 1908. Mr. Phelps shows that infant mortality has declined less than is commonly believed, and that its apparent decline is often due to inaccurate and misleading statistics.

infants. The other is on the hypothesis of the comparative neglect of hygiene among adults. It is surprising that this latter alternative has not been given due consideration.

Every detail of infant life has latterly been made the subject of special study, and every mother of common intelligence has tried to learn and to apply the results of that study. The times of the baby's meals, the quantity of its feeding, the modification and sterilization of cow's milk, the hours of sleep, the ventilation of sleeping rooms, and other innumerable details are now attended to with scrupulous care. The change in these respects, even within the memory of most persons now living, is striking. The children have reaped the reward. But no corresponding change has taken place in the habits of the adult population. Many families buy one grade of milk for the babies, and another cheaper grade for the rest of the family. This they regard as "economy." Parents require their children to keep regular and suitable hours for sleep, but "owl it" themselves. They will keep their children out of doors, and send them into the country, but subject themselves to the dust, smoke, and close air of the workroom and places of business. They will not allow their children to use alcohol or tobacco, or even tea or coffee, much less opium, chloral, or other habit-forming drugs, but they take these themselves as a matter of course. They are now insisting on playgrounds for children, but their own amusements are sought in the unhygienic theater, or maybe in the saloon or immoral resort. The child is protected on all sides, with the result that he sometimes lives almost an ideal animal life, with its due proportion of amusement, exercise, rest, and sleep. The parents themselves are tied down to drudgery, overwork, worry, and long hours. The difference, when we reflect upon it, is startling. We make hygiene paramount for our children; for ourselves we neglect it totally, partly from the idea of sacrificing ourselves for the sake of our children, partly from necessity, real or imagined, and partly from the thraldom of habit already formed. With such a contrast between the recent improvement of hygiene in childhood and the lack of improvement in middle life, one need not wonder that the mortality of one period has improved and that of the other has not. We do not need to invoke the aid of the theory that weak lives have been more prolonged than strong lives. The moral is that hygiene should not stop in childhood. It is natural and proper, however, that the first attempt to apply hygienic knowledge should begin with children. It is through children that new ideas usually make their way into custom. "You can't teach an old dog new tricks." Grown persons have habits already formed, and when once a habit is formed it is difficult to change it.

Habits of living among adults have even grown worse in some respects. Observing practitioners comment on the increasing nervous tension in modern life. The rush of the railway train, the telephone, the elevator are at once an outgrowth and an excitant of this increased tension. They are life's pace makers, and the pace is ever quickened. The health officer of New York City attributes to this severer strain the increase of heart and nervous diseases. It would be interesting to know the relative prevalence of adult diseases under conditions of reposeful and exciting surroundings and occupations, but I know of no investigation on this phase of the subject.

While this report was being written the recent figures from Great Britain came to hand. They show that the tendency of the death rates among the later ages to increase seems to have given place to a slightly opposite tendency. The expectation of life at ages 40, 60, and 80 during the decade of 1891–1900 has a little more than held its own as compared with the previous decade.

SECTION 2.—*Children's diseases impair both fit and unfit.*

Another point needs emphasis. When it is said that the lives of weak infants are prolonged it is commonly overlooked that the same causes also prolong the lives of the strong, and, reversely, that unhygienic conditions which tend to exterminate the weak tend also to shorten the lives of the strong. Bad hygiene is merely a common handicap for all classes. The burden of proof is upon those who claim that it has a differential effect and increases the process of weeding out the unfit. This weeding-out process goes on whether there is a great or a small obstruction to overcome. Bad air and children's epidemics are the common environment of all. While this must produce a greater mortality, it remains to be shown that it would be more selective.

That a high infant mortality does not tend to lengthen life, but rather to stunt all life, would seem to be indicated by the evidence, so far as it can be interpreted. Russia, for instance, has a high infant mortality. If the statistics are to be trusted, it is 70 per cent greater than in the United States; yet Moscow and St. Petersburg have a general mortality rate which greatly exceeds that of similar cities in this country.

It may be that the more unfavorable the struggle for existence the more rapidly will natural selection result in improved vitality. But even if this were true, it would not imply that in a more favorable environment selection would cease. And it may not be true. It may be that adversity, if too severe, will crush and injure the survivor as well as eliminate the unfit. We do not look for the best trees on the bleak mountain top, but in the genial valley. As we go up the struggle for existence increases, until even the sturdiest fail to thrive above the "timber line."

> The farmer who tries to improve his stock does not select hardships. Cold and starvation are now negligible quantities in the great ranches, and the breeds that were notable for ability to withstand them give way to varieties that may be adapted to neither emergency.[a]

Venereal diseases, hook-worm disease, malaria, and many other maladies shorten and weaken life, whether of weak or strong. Referring to the racial degeneration probably caused by malaria on the sturdy Greek, Maj. Ronald Ross said, in an address before the Oxford Medical Society, November 29, 1906:[b]

> Now what must be the effect of this ubiquitous and everlasting incubus of disease on the people of modern Greece? Remember that the malady is essentially one of infancy among the native population. Infecting the child one or two years after birth, it persecutes him until puberty with a long succession of febrile attacks. * * * Imagine the effect it would produce upon our own

[a] Simon N. Patten, The New Basis of Civilization, New York (Macmillan), 1907.

[b] This quotation is from Dr. L. O. Howard's report to the Conservation Commission on "Economic loss to the people of the United States through insects that carry disease."

children here in Britain. * * * What would be the effect upon our population, especially our rural population—upon their numbers and upon the health and vigor of the survivor? It must be enormous in Greece. People often seem to think that such a plague strengthens a race by killing off the weaker individuals; but this view rests upon the unproven assumption that it is really the weaker children which can not survive. On the contrary, experience seems to show that it is the stronger blood which suffers most—the fair, northern blood which nature attempts constantly to pour into the southern lands.[a] If this be true, the effect of malaria will be constantly to resist the invigorating influx which nature has provided; and there are many facts in the history of India, Italy, and Africa which could be brought forward in support of this hypothesis. * * * In prehistoric times Greece was certainly peopled by successive waves of Aryan invaders from the north. * * * That race reached its climax of development at the time of Pericles. * * * Suddenly, however, a blight fell over all. Was it due to internecine conflict or to foreign conquest? Scarcely, for history shows that war burns and ravages, but does not annihilate. Thebes was thrice destroyed, but thrice rebuilt. Or was it due to some cause, entering furtively and gradually sapping away the energies of the race by attacking the rural population, by slaying the newborn infant, by seizing the rising generation, and especially by killing out the fair-haired descendant of the original settlers, leaving behind chiefly the more immunized and darker children of their captives, won by the sword from Asia and Africa? * * * I can not imagine Lake Kopais, in its present highly malarious condition, to have been thickly peopled by a vigorous race; nor, on looking at those wonderful figured tombstones at Athens, can I imagine that the healthy and powerful people represented upon them could have ever passed through the anæmic and "splenomegalous" infancy (to coin a word) caused by widespread malaria. Well, I venture only to suggest the hypothesis, and must leave it to scholars for confirmation or rejection. Of one thing I am confident—that causes such as malaria, dysentery, and intestinal entozoa must have modified history to a much greater extent than we conceive.

Evolution in human society is a wonderfully complex thing. Survival of the races has long been dependent on a long period of protection of children by parents, and may in future even depend on protection of other kinds.[b]

SECTION 3.—*Fitness is relative to environment.*

Whether or not degeneration is actually going on is a question for which the data are insufficient for us to form an intelligent generalization. That there are very strong forces working in that direction can not be questioned, but there are also very strong forces working in the opposite direction. In discussing degeneration, one point must be borne in mind which has often been forgotten by writers on the subject. Man's fitness to live is relative to the environment in which he is to live. If muscular strength decreases, it is not a sign of degeneration, provided muscular strength is no longer needed. One does not speak of hothouse grapes as degenerates. They doubtless lack the hardy characteristics of wild grapes, but these characteristics are not needed in a hothouse.

If it should prove true that in some directions humanitarian impulses betray us into favoring the survival of the unfit and their perpetuation in the next generation, such shortsighted kindness must be checked. But all the dangers of perpetuating vital weaknesses can be avoided if proper health ideals are maintained. For when such

[a] Physicians maintain that some diseases, especially typhoid fever and pneumonia, are more apt to attack the strong than the weak.

[b] See Prince Kuropatkin, "Mutual Aid a factor in Evolution," New York (McClure-Phillips), 1902.

health ideals become a national possession fewer weak infants will be born into the world. This will come about in three ways: First, marriage and "sterilization" laws will reduce the number of marriages of degenerates. Secondly, parents will be more careful of transmitting disease or weakness to their offspring. There is strong reason to believe that inheritance depends largely upon the physical condition of both parents at the time of conception. If at such a time either parent, or both parents, are in a state of intoxication or sufferers from venereal disease, this lack of hygiene on their part will affect the heredity of the offspring. Immorality, which practically means lack of sex hygiene, never strengthened a race; on the contrary it has been the most potent cause of race extinction (of the Hawaiians, Indians, negroes, and others).[a] Thirdly, the influence of higher ideals of health and vitality will tend both to restore the attraction of a strong and beautiful physique to its rightful place among the various attractions which lead to marriage, and to lessen the allurements of such extraneous attractions as wealth.

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[a] See F. L. Hoffman, "Race Traits and Tendencies of the American Negro," Publication of American Economic Association, Ch. VII. August, 1896.

Part IV.—RESULTS OF CONSERVING LIFE.

Chapter XI.—*Prolongation of life.*

Section 1.—*Life is lengthening.*

We have already seen evidence of the possibility of prolonging life: In Europe the life span is double what it is in India. The death rate of Dublin is over twice that of Amsterdam, and three times that of rural Michigan. Again, making every allowance for inaccuracies of old records, we have strong reason to believe that life is twice as long as three or four centuries ago, and modern accurate records show that it is to-day increasing more rapidly than ever. The rate at which this lengthening proceeds per century is shown in the following table, based on Chapter I.

Rate of lengthening life (in years, per eentury).

Country.	Periods.	Males.	Females.
England	1838–1854 to 1871–1881, or 30 years	5	9
Do	1871–1881 to 1891–1900, or 20 years	14	16
France	1817–1831 to 1898–1903, or 76 years	10	11
Prussia	1867–1877 to 1891–1900, or 23 years	25	29
Denmark	1835–1844 to 1895–1900, or 57 years	13	15
Sweden	1816–1840 to 1891–1900, or 67 years	17	15
United States:			
Massachusetts	1789 to 1855, or 66 years	7	
Do	1855 to 1893–1897, or 40 years	14	
India	1881 to 1901, or 20 years	0	

From this table we observe:

First. That the rate of progress is extremely variable in different countries. It is perhaps no accident that the maximum rate obtains in Prussia, which is probably the most progressive country in the discovery and application of scientific medicine. If progress continues for a century at merely the present rate, human life in Prussia will be twenty-five to twenty-nine years longer than at present. The average rate of improvement for all the countries, excepting India, is about fifteen years per century.

Second. It is noticeable that in practically all cases the improvement is more among females than males. This is one expression of the progress which womankind is now making in all lands.

Third. This table, as well as the estimate of Professor Finkelnburg already quoted, shows that not only is the average duration of human life increasing, but that the rate of increase is also increasing. The estimate of Finkelnburg that the lengthening of life during the interval between the sixteenth century and the end of the eighteenth century was from eighteen or twenty years to a little over thirty years shows a rate of increase of about four years per century. During the following century he estimated that the life span increased from a little over thirty to thirty-eight or forty years, or about nine years per century. In the table we see that in England the length of life was increasing in the middle of the nineteenth century at a rate of from five to nine years per century, while during the last quarter it was increasing at from fourteen to sixteen years per century. In Massachusetts the imperfect data indicate that life lengthened in the first half of the eighteenth century at the rate of about seven years a century. The indication for the last part of the nineteenth century is that it increased at the rate of fourteen years per century.

We may briefly summarize chronologically the general rate of increase as follows:

Lengthening of human life per century.

	Years.
During seventeenth and eighteenth centuries	4
During first three quarters of the nineteenth century	9
Present rate in Massachusetts	14
Present rate in Europe	17
Present rate in Prussia	27

SECTION 2.—*Table showing further practicable prolongation.*

It would be surprising if the future should not witness a further lengthening of human life, and at an increasing rate. Of course there is a limit to the further increase of human life, but there is good reason to believe that the limit is still far off.

The following table[a] shows that at least fourteen years could be added to human life by the partial elimination of preventable diseases according to the stated ratios of preventability. This is equivalent to a reduction in the death rate of about 25 per cent. The table is based on the causes of death given in the census volume for mortality statistics for 1906. These causes are arranged according to the average, or rather median,[b] age at death from the disease. This median age is given in the second column. The order in this column shows at a glance the successive onslaught of, or rather fatality from, the various causes of death. The table shows the successive bombardments of disease to which human life is subject.

The third column gives the average lost "expectation of life;"[c] that is, the expectation cut off by each particular cause of death.

The fourth column represents the percentage which the deaths from each particular cause bear to the total number of deaths in 1906 in the registration area. It shows the relative importance of the different causes of death in the present death rate, but has no reference to the age at death.

The fifth column contains an estimate, made by physicians, of the ratio of preventability of deaths from each cause named.

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[a] For detailed statement in regard to the construction of this table, see appendix to this chapter.

[b] By the "median" age at death is meant the age such that one-half of the deaths occur earlier and one-half later than this age. The "median" is a species of average, but differs from the ordinary arithmetical average. It has the great advantage of ease of computation.

[c] The "expectation" is taken from the figures of Abbott for Massachusetts, 1893–1897, and is the average of expectation of males and females. See Report State Board of Health for Massachusetts, 1898.

The items in the sixth column are found by multiplying together those in the fourth and fifth columns, and express the percentage which the preventable deaths from each cause named bears to the total number of deaths from all causes.

The seventh and last column gives the figures for which the table is constructed, namely, the amount of prolongation of life which would come about through preventing deaths according to the ratios of preventability in column 5. When it is said that a death is preventable, it is not, of course, meant that the person saved from it will never die, but merely that his death is postponed. The term "postponable" would avoid a great deal of confusion on the subject.

The principle on which the last column is constructed is simply the principle of averages. The column shows the prolongation of life which would be caused by postponing the "postponable" deaths by the amounts indicated in column 3. To illustrate this principle, suppose ten magnitudes to be averaged arithmetically, and that their average is thirty. To fix our ideas, we may suppose these ten magnitudes to be represented by ten lines drawn on a sheet of paper. It is evident that if one of these ten lines is prolonged the average of the ten will be thereby increased by exactly one-tenth of the prolongation of that one line.

Possible prolongation of life.

(1) Cause of death.	(2) A. Median age of deaths from causes named.	(3) B. Expectation of life at median age.	[b](4) C. Deaths due to cause named as percentage of all deaths.	(5) D. Ratio of preventability (postponability), i. e., ratio of "preventable" deaths from cause named to all deaths from cause named.	(6) E=CD. Ratio of "preventable" deaths from cause named to all deaths from all causes.	(7) F=BE. Years added to average lifetime if deaths were prevented in the ratio of preventability of column 5.
	Years.	*Years.*	*Per cent.*	*Per cent.*	*Per cent.*	*Years.*
1. Premature birth	1	50	2	40	0.8	0.4
2. Congenital malformation of heart (cyanosis)	1	50	.55	0	....	....
3. Congenital malformations other than of heart	1	50	.3	0	....	....
4. Congenital debility	1	50	2.3	40	.92	.46
5. Hydrocephalus	1	50	.1	0	....	....
6. Venereal diseases	1	50	.3	70	.21	.11
7. Diarrhea and enteritis	1	50	7.74	60	4.64	2.32
8. Measles	1	50	.8	40	.32	.16
9. Acute bronchitis	1	50	1.1	30	.33	.17
10. Broncho-pneumonia	1	50	2.4	50	1.2	.6
11. Whooping cough	1	50	.9	40	.36	.18
12. Croup	2	54	.3	75	.22	.12
13. Meningitis	2	54	1.6	70	1.12	.6
14. Diseases of larynx other than laryngitis	3	54	.07	40	.03	.02
15. Laryngitis	3	54	.06	40	.02	.01
16. Diphtheria	3	54	1.4	70	.98	.53
17. Scarlet fever	3	54	.5	50	.25	.14
18. Diseases of lymphatics	5	54	.01	20	.002	.001
19. Tonsilitis	8	52	.05	45	.02	.01
20. Tetanus	8	52	.19	80	.15	.08
21. Tuberculosis other than of lungs	23	40	.17	75	.13	.05
22. Abscess	24	39	.08	60	.05	.02
23. Appendicitis	24	39	.7	50	.35	.14
24. Typhoid fever	26	38	2	85	1.7	.65
25. Puerperal convulsions	28	[a]37	.2	30	.06	.02

[a] "Expectation" for females.

[b] As to some inaccuracies in this column, see Appendix to this chapter, section 4.

Possible prolongation of life—Continued.

(1) Cause of death.	(2) A. Median age of deaths from causes named.	(3) B. Expectation of life at median age.	(4) C. Deaths due to cause named as percentage of all deaths.	(5) D. Ratio of preventability (postponability), i. e., ratio of "preventable" deaths from cause named to all deaths from cause named.	(6) E=CD. Ratio of "preventable" deaths from cause named to all deaths from all causes.	(7) F=BE. Years added to average lifetime if deaths were prevented in the ratio of preventability of column 5.
	Years.	*Years.*	*Per cent.*	*Per cent.*	*Per cent.*	*Years.*
26. Puerperal septicemia	28	a 37	0.4	85	0.34	0.13
27. Other causes incident to childbirth	31	a 35	.36	50	.18	.06
28. Diseases of tubes	31	a 35	.1	65	.06	.02
29. Peritonitis	31	34	.5	55	.28	.1
30. Smallpox	32	34	.01	75	.01	.003
31. Tuberculosis of lungs	33	33	9.9	75	7.42	2.45
32. Violence	34	32	7.5	35	2.7	.86
33. Malarial fever	34	32	.2	80	.16	.05
34. Septicemia	34	32	.3	40	.12	.04
35. Epilepsy	35	32	.29	0	....	....
36. General, ill defined, and unknown causes (including "heart failure," "dropsy," and "convulsions")	35	31	9.2	30	2.75	.85
37. Erysipelas	37	30	.3	60	.18	.05
38. Pneumonia (lobar and unqualified)	37	30	7	45	3.15	.94
39. Acute nephritis	39	29	.6	30	.18	.05
40. Pleurisy	42	27	.27	55	.15	.04
41. Acute yellow atrophy of liver	42	27	.02	0	....	....
42. Obstruction of intestines	43	26	.6	25	.15	.04
43. Alcoholism	44	25	.4	85	.34	.09
44. Hemorrhage of lungs	45	25	.1	80	.08	.02
45. Diseases of thyroid body	46	24	.02	10	.002	.0005
46. Ovarian tumor	46	a 25	.07	0	....	....
47. Uterine tumor	46	a 25	.1	60	.06	.02
48. Rheumatism	47	23	.5	10	.05	.01
49. Gangrene of lungs	48	23	.03	0	....	....
50. Anemia, leukemia	48	23	.4	50	.2	.05
51. Chronic poisonings	48	23	.05	70	.03	.007
52. Congestion of lungs	49	22	.4	50	.2	.04
53. Ulcer of stomach	49	22	.2	50	.1	.02
54. Carbuncle	49	22	.03	50	.015	.003
55. Pericarditis	52	20	.1	10	.01	.002
56. Cancer of female genital organs	52	a 21	.6	0	....	....
57. Dysentery	52	20	.5	80	.4	.08
58. Gastritis	53	19	.65	50	.32	.06
59. Cholera nostras	53	19	.09	50	.05	.01
60. Cirrhosis of liver	54	19	.9	60	.54	.1
61. General paralysis of insane	55	18	.3	75	.22	.04
62. Hydatid tumors of liver	55	18	.002	75	.002	.0003
63. Endocarditis	56	17	.8	25	.2	.03
64. Locomotor ataxia	56	17	.17	35	.06	.01
65. Diseases of veins	57	17	.04	40	.02	.003
66. Cancer of breast	58	a 17	.4	0	....	....
67. Diabetes	58	16	.8	10	.08	.01
68. Biliary calculi	58	16	.17	40	.07	.01
69. Hernia	59	16	.27	70	.19	.03
70. Cancer not specified	59	16	.9	0	....	....
71. Tumor	59	16	.08	0	....	....
72. Bright's disease	59	16	5.6	40	2.24	.36
73. Embolism and thrombosis	60	15	.26	0	....	....
74. Cancer of intestines	60	15	.5	0	....	....
75. Cancer of stomach and liver	61	14	1.7	0	....	....
76. Calculi of urinary tract	61	14	.03	10	.003	.0004
77. Cancer of mouth	63	13	.1	0	....	....
78. Heart disease	63	13	8.1	25	2.02	.26
79. Influenza	64	13	.7	50	.35	.05
80. Asthma and emphysema	64	13	.23	30	.07	.009
81. Angina pectoris	65	12	.4	25	.1	.01
82. Apoplexy	67	11	4.4	35	1.54	.17
83. Cancer of skin	70	10	.2	0	....	....
84. Chronic bronchitis	71	9	.8	30	.24	.02
85. Paralysis	71	9	1	50	.5	.04

a "Expectation" for females.

Possible prolongation of life—Continued.

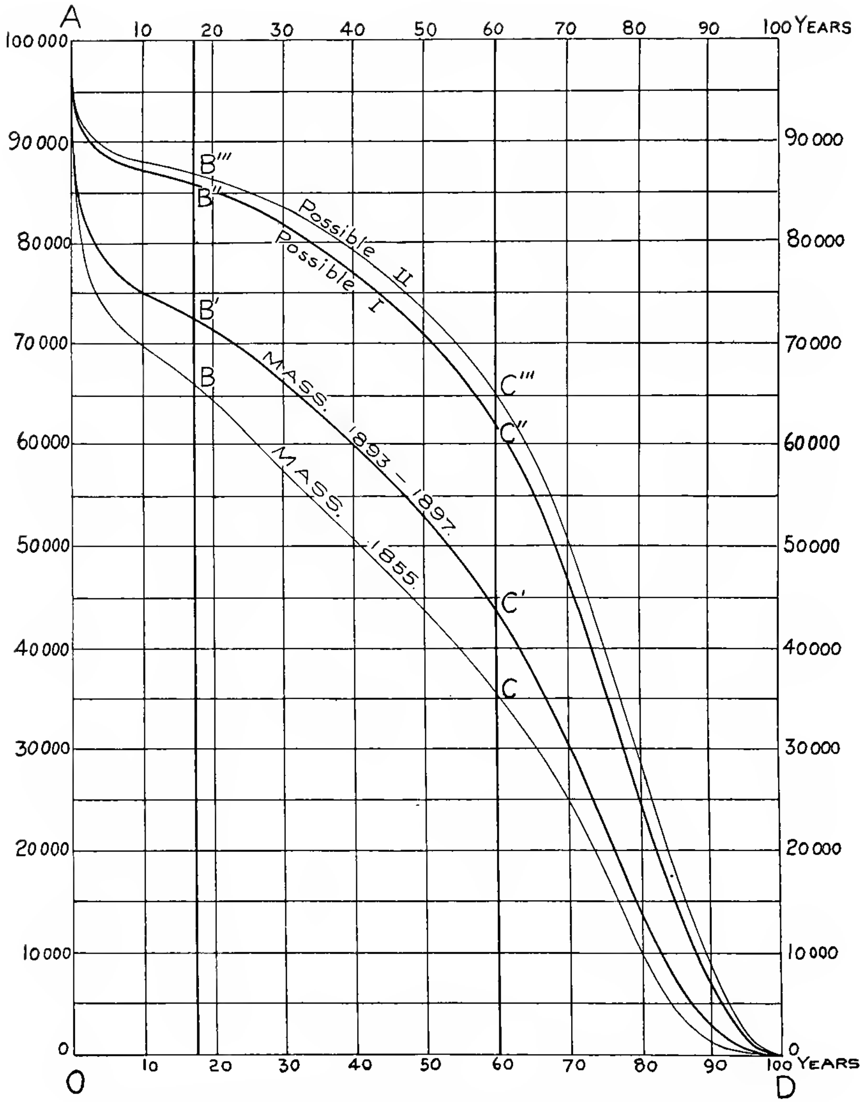
(1) Cause of death.	(2) A. Median age of deaths from causes named.	(3) B. Expectation of life at median age.	(4) C. Deaths due to cause named as percentage of all deaths.	(5) D. Ratio of preventability (postponability), i. e., ratio of "preventable" deaths from cause named to all deaths from cause named.	(6) E=CD. Ratio of "preventable" deaths from cause named to all deaths from all causes.	(7) F=BE. Years added to average lifetime if deaths were prevented in the ratio of preventability of column 5.
	Years.	*Years.*	*Per cent.*	*Per cent.*	*Per cent.*	*Years.*
86. Softening of brain	71	9	0.2	0	....	....
87. Diseases of arteries	73	9	0.83	10	0.08	0.007
88. Diseases of bladder	74	8	0.2	45	0.09	0.007
89. Gangrene	74	8	0.25	60	0.15	0.01
90. Old age	83	5	2	0	....	....
All causes	38	....	100	42.3	[a]42.3	14.06
RÉSUMÉ.						
Diseases of infancy (having median age 1)	....	....	18.5	47	8.8	4.4
Diseases of childhood (having median age 2 to 8)	....	....	4.2	67	2.8	1.51
Diseases of middle age (having median age 23 to 49)	....	....	43	49	21.2	6.82
Diseases of late life (having median age 52 to 83)	....	....	34.3	28	9.5	1.33
All causes	....	....	100	42.3	42.3	14.06

[a] Although this is the ratio of general preventability of deaths under existing conditions, the death rate, i. e., deaths in relation to population, will not in the end be affected in this ratio but by only about 25 per cent. The reason for this paradox is that deaths prevented lead to a larger population (See appendix to this chapter, section 3).

Similarly, if of the ten lines three are prolonged each a certain stated amount, or are prolonged that amount on the average, the average of the whole ten will be increased by three-tenths of this amount. Consequently, if the saved lives from typhoid fever (No. 24 in the table) are, on an average, prolonged thirty-eight years, and these saved lives represent 1.7 per cent of all lives, the average life will be prolonged by 1.7 per cent of thirty-eight years. This is 0.65 or two-thirds of a year.

All the calculations are on the assumption of expectations of life, such that the saved lives will die according to the present law of mortality. Consequently, if the table should be corrected by substituting in each case such an expectation of life as would conform to the improved mortality, the result would be an addition (2.1 years)[a] to the estimate of possible prolongation, which would therefore become 16.2 years. The résumé of the table shows that of the 14 years of possible prolongation of life 4.4 would be caused by reducing infant deaths under or near 1 year, 1.51 by reducing mortality from children's diseases, 6.82 from reducing the diseases of middle life, especially tuberculosis and typhoid, and only 1.33 by reducing the mortality of diseases the deaths from which usually come after 50 years of age.

[a] Best estimated graphically, as shown in appendix to this chapter.



SURVIVORSHIP CURVES, SHOWING SAFE MINIMUM IMPROVEMENT ATTAINABLE.

The table shows that seven of the 90 causes of death are responsible for over half of the shortening of life, namely, diarrhea and enteritis (No. 7), broncho-pneumonia (No. 10), meningitis (No. 13), typhoid (No. 24), tuberculosis of lungs (No. 31), violence (No. 32), and pneumonia (No. 38). These alone shorten life needlessly by more than eight years. Against these seven causes, therefore, our special efforts should be directed. Pure milk, pure water, pure air, and reasonable protection from accident are the chief means known at present. When the public makes up its mind no longer to endure impure milk, impure water, and impure air, and unreasonable dangers to life and limb, life will lengthen eight years, and probably a great deal more.

In the résumé of the table columns 4, 6, and 7 are found from the original table by simple addition. Each figure in the fifth column is found by dividing the figure in the sixth by that in the fourth.[a]

The final figure in this column, 42.3, is the same as the sum of column 6, and means that according to medical opinion 42.3 per cent of the deaths which occur under present conditions are preventable (postponable). The death rate, however, will ultimately be reduced, not in this proportion, but by about 25 per cent,[b] while the average duration of life will be increased about $33\frac{1}{3}$ per cent.

SECTION 3.—*Diagram showing effect of prolongation at different ages.*

The whole process is best seen by means of a survivorship table, a diagram of which follows:

We have here four curves which represent the survivors in successive years from a hypothetical and representative list of 100,000 persons born. The two of these curves which should be noted are the inner two, namely, those labeled "Mass. 1893–97" and "Possible I." The former is taken, in lieu of any better statistics, as representing the existing law of mortality in the United States. The latter shows what the law of mortality would be if the ratios of preventability given in the preceding table were put in force. The curve Possible I is constructed on the supposition that all the deaths prevented or postponed subsequently occur according to the present law of mortality; that is, that expressed in the curve Mass. 1893–97.

The two remaining, or outer, curves are given merely for comparison. The lowest, marked "Mass. 1855," shows the mortality which held true in Massachusetts in that year according to the estimates of the actuary, E. B. Elliott.[c] The difference between this curve and the one above shows the number of years of life actually saved to 100,000 persons subject to the mortality of 1893–1897 instead of the mortality of 1855. The upper curve (Possible II) shows the modification in Possible I on the assumption that the saved lives, instead of following the present law of mortality (Massachusetts,

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[a] The result is in each case a weighted average of the individual ratios of preventability for the individual causes of death.

[b] See appendix.

[c] See Proceedings of the American Association for the Advancement of Science, 1857, pp. 61, 69; also Sixteenth Registration Report, Massachusetts, 1857, p. 204.

1893–1897), follow the law of mortality represented in the curve Possible II itself.[a]

This diagram shows at a glance what improvement has been made in mortality and at what ages, and what improvement is still possible, and at what ages, according to the preventability known to be easily possible. We see that the curve, Possible I, does not drop as far in the first year of life as the curve Mass. 1893–97. This is because of the great saving of infant lives known to be possible. The years of life which would be saved to the 100,000 persons by the new hygiene are represented by the difference in area between the new curve AB″C″D and the old curve AB′C′D, from which it was constructed by applying the ratio of preventability. This area can easily be measured by a planimeter, and is found to be 1,280,000, which, divided by the 100,000 persons, means an average addition of 12.8 years to the lifetime of each person born. This result differs somewhat from the arithmetical calculation, 14.06, given in the preceding table.[b] If the upper curve be used, which assumes that the "saved" lives die not according to the old but the new mortality, the addition becomes not 12.8 but 14.9 years, as against the 16.1 computed arithmetically. We may hereafter refer to this minimum estimate of possible increase of life as, in round numbers, 15 years. The lengthening of life would be from 45 to 60, or one-third.

The diagram also shows the saving of life which actually took place between 1855 and the period 1893–1897. The area between the curves for these two periods shows that 550,000 years were saved for a supposed group of 100,000 persons, or 5.5 per person. The whole area of the new curve AB″C″D is 5,810,000, or 58.1 years per person, which is the new average duration of life, as compared with 45.3 for 1893–97 and 39.8 years for 1855. We may divide the diagram by two vertical lines drawn at the ages 17½ and 60 in order to discover what part of the added life occurs between these ages—that is, within the working period—and what parts fall on either side. The addition of 12.8 years to the lifetime of each of 100,000 persons, or 1,280,000 years of life in all, is divided into three groups, namely, the years falling in the period of preparation, 200,000; in the working

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[a] The method of constructing the curves Possible I and Possible II from the curve Mass. 1893–97 is by means of the ratios of preventability given in the résumé of the preceding table. See appendix.

[b] The discrepancy, 1.3 years, is due to the fact that in constructing the table, based on individual diseases, I was compelled to use for the percentages of deaths by ages (column 4) the percentages obtaining in the calendar year 1906; whereas the diagram is based on the idea of a stationary population, the distribution of the deaths being represented by the shape of the curve Mass. 1893–97. The diagramatic method is therefore more correct. The abnormal age distribution in 1906 results in making some of the figures in the last column of the table too large and some too small. In a general way, the figures for the earlier ages are too large and for the later ages too small, although the figures which are most too large are probably for ages 30 to 35. Consequently the greatest error in excess is for tuberculosis, which is possibly three-fourths of a year too large. No exact corrections are possible, and any systematic corrections, even inexact, would be very laborious. This would correspond to the elaborate actuarial calculations of Hayward in England and Glover in the United States. See Hayward "On the Construction of Life Tables and on Their Application, etc." Haydock and J. W. Glover, "A Study of Tuberculosis in the United States," Journal of Michigan State Medical Society, February, 1909.

period, 680,000; in the period of decline, 400,000. The following table will show the whole process:

	Preparatory period (ages 0–17½).		Working period of life (17½–60).		Period of decline (60 and beyond).		Total.	
	Years of life.	Per cent of total.	Years.	Per cent.	Years.	Per cent.	Years.	Per cent.
Mass. 1855	12.6	32	21.9	55	5.3	13	39.8	100
Mass. 1893–97	13.5	30	25.0	55	6.8	15	45.3	100
Possible I	15.4	26	31.8	55	10.9	19	58.1	100

These figures show that in 1855 the average person born lived only 12.6 years of the 17½ years in the period of preparation for life. In 1893–97 he lived 13.5 years. If modern hygiene were applied according to the ratios of the assigned preventability, the figure would then be 15.4 years actually lived out of the 17½. Of the working period of 42½ years (17½–60, the average man living under the mortality of 1855 had only about half, or 21.9 years; under the mortality of 1893–97 he had 25.0. and under the "Possible I" mortality he would have 31.8 years.

In percentage the years in the working period remain 55 per cent of the total life in all cases. This assumes that with the prolongation of life the limits of the working period remain 17½ and 60. Since the prolongation of life carries with it a postponement of the age of disability, it follows that the proportion of working life would actually increase.[a]

It will be seen in comparing the curves on the diagram that the change wrought in the character of the mortality curve by the new hygiene simply continues the change already in progress. The family resemblance between all four curves is striking.

SECTION 4.—*Fifteen years a safe minimum estimate of prolongation possible.*

The estimate of fifteen years as the possible prolongation of life is merely a minimum estimate. This will be seen from the following important considerations:

1. The estimate takes no account of future medical discoveries, which are now coming at such a rate that we have every reason to believe they will soon greatly increase the ratios of preventability. Cancer, for instance, has been put down with zero as its ratio of preventability, but the scientific world is intently seeking for methods of prevention and cure. Likewise "old age" has been assumed as unpreventable. Yet Metchnikoff maintains with reason that this is a malady which can be postponed.

2. The ratio of preventability of the above diseases takes little account of the cumulative influence of hygiene. Certain diseases late in life are now taken to be unpreventable or only slightly preventable on the assumption that people reach those ages in their present degree of more or less imperfect health. But on the assumption that personal hygiene had been practiced since birth, the vital resistance, which is always a deterrent of disease, would have been strengthened.

[a] See Dr. Edward Jarvis, "Political Economy of Health," Fifth Annual Report, Mass. Board of Health, 1874, p. 338, ff.

Professor Sedgwick tells us that evidence will be published demonstrating "Hazen's theorem," that every life saved from typhoid by better water supply means two or three persons saved from deaths from other causes. Our table shows an estimate of at least 85 per cent as the preventability of typhoid, but the coincident preventability of other diseases which this prevention of typhoid would bring about finds no place in the table. The individual estimates given for these other diseases take no account of such indirect action. Similarly, as Metchnikoff has emphasized, venereal diseases, though they seldom cause death, do shorten life, the "terminal disease" being quite different. The same is true of malaria and hook-worm disease, which predispose to tuberculosis and other terminal diseases. But in the table the ratios of preventability of tuberculosis and other diseases were constructed quite irrespective of any effect from reducing venereal diseases, malaria, and other devitalizing diseases.

In the matter of personal hygiene the cumulative influence is still more indirect, and perhaps still more powerful. It is now often remarked by insurance men that the best risks are not necessarily the best physiques, but may be the valetudinarians who practice personal hygiene.

There is a vicious circle of disease and a beneficent circle of health. The so-called "cause of death" given in death certificates is only the terminal cause. It is often merely the "last straw" of a terrible load gradually accumulated through life.

Evidently, to exploit the resources of hygiene, we need to consider a thoroughgoing change in health ideals and a consequent revolution in the conditions and habits of living. What would then happen to human longevity we can only conjecture. The possible addition to the life span might, for aught we know, be several times the fifteen years in the table.

3. The figures for the possible prolongation of life take no account of the ultimate racial effects of the new health ideals. If once a nation becomes thoroughly alive to the importance of maintaining the stamina of its citizens, this will, as we have seen, affect marriages—by putting a premium on health as one of the desiderata in a prospective husband or wife. The longevity of succeeding generations would certainly be improved—how much, it would be useless to guess.

The foregoing considerations, added to the fact that the estimates of preventability were made conservatively, will show that the addition of fifteen years is really only a first step. If clean milk will prevent infantile diarrheal diseases, if clean water will prevent deaths from typhoid and at the same time—according to Hazen's theorem—prevent two or three times as many other deaths, and if clean air will prevent tuberculosis, then it is evident that mere cleanliness in respect to these necessities will suffice to lengthen life by most if not all of the above estimate. Fifteen years is merely the "ore in sight." If we will work for it, we may get an even richer prize.

> Within the past few years the knowledge of the causes of disease has become so far advanced that it is a matter of practical certainty that by the unstinted application of known methods of invesigation and consequent controlling action, all epidemic disease could be abolished within a period so short as fifty years.[a]

[a] E. Ray Lankester, "The Kingdom of Man," New York (Holt), 1907, p. 36.

SECTION 5.—*Need of lengthening human life.*

If Metchnikoff's noble dream should be some day realized, the lengthening of human life would at once decrease the burden on the productive period. That period tends to remain 55 per cent of the total years lived, on the assumption that the working period remains 17½ to 60, but the upper limit tends to shift forward. In this way, both the absolute and relative length of the working period would be increased.

The further off the burden of old age is shifted, the easier it is for society or the individual to accumulate the wealth to provide for it. At present the burden of helpless old age is extremely serious, as those countries are beginning to realize which, like Denmark, Belgium, Germany, France, and recently England, have enacted laws to provide old-age pensions.

As life becomes more complex it requires a longer period of preparation. Preparation is education, and requires time. As the stock of knowledge increases, the period for acquiring it, or rather only enough of it to enable one to earn a livelihood, is constantly tending to increase. The age of leaving school and college is presumably growing greater.

It would be very much in keeping with the fitness of things if in this century biological science practically applied should shift the limit of the further end of the working period, the limit which we have assumed to be 60, to a later period of life. Human life would then be on a larger scale throughout. It would provide time for a longer and more thorough preparation and at the same time provide sufficient years of working life to repay this investment.

As Metchnikoff[a] well points out, one result of lengthening life will be a greater utilization of accumulated experience. We shall have less immaturity of judgment. The principle which leads to the choice for members of the judiciary of men of ripe years and knowledge will apply to every field of human activity, even those fields which are now preempted by young men because of the necessity of utilizing their vitality. It will lead to a sane and yet a vigorous conservatism. It will give to society a body of old yet hale men of experience, whose influence and worth can not be measured. As Metchnikoff has said:

> Old age, at present practically a useless burden on the community, will become a period of work valuable to the community. As the old man will no longer be subject to loss of memory or to intellectual weakness, he will be able to apply his great experience to the most complicated and the most delicate parts of the social life.[b]
>
> We may predict that when science occupies the preponderating place in human society that it ought to have, and when knowledge of hygiene is more advanced, human life will become much longer and the part of old people will become much more important than it is to-day.[c]

SECTION 6.—*The normal lifetime.*

What is the normal human lifetime?[d] Many estimates have been made, based on all sorts of reasoning, the figures extending from 75

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[a] Prolongation of Life, p. 329.

[b] Nature of Man, p. 295.

[c] Metchnikoff: "Prolongation of Life," pp. 226–227.

[d] On the topic of human longevity, see Metchnikoff: "The Prolongation of Life," Pt. II, Chaps. I, II. Shaler: "The Individual," New York (Appleton), 1901, Chap. III. Lankester: "Comparative Longevity," London, 1870, pp. 88–119.

to 200 years. Flourens's law, of doubtful value, that a mammal lives five times the length of its growing period, can not be applied generally. It is true, the horse full grown at 5 may live 25 years; sheep adult at less than 3 years may live 12; while elephants, which have an unusually tardy development, are reputed to have a lifetime of 2 centuries.

Haller, a distinguished Swiss physiologist of the eighteenth century, thought that man ought to live to 200 years; Buffon was of the opinion that when a man did not die from some accident or disease he would reach 90 or 100 years.[a]

In man the growth period is normally continued to some time after the twentieth year; its exact limit has not been ascertained, but from the statistics gathered by the Sanitary Commission during the civil war it seems most likely that it is not usually completed until after the thirtieth year.[b]

One method which has been suggested to ascertain the natural length of life is to suppose all diseases to be completely eliminated and those who now die of them to die of old age. The median age for death from old age is 83. Metchnikoff, however, shows the error of assuming present old age to be normal. We may conclude that the normal life exceeds 83.

There must needs be, of course, a limit to the possible prolongation of life. We find in recent times few authenticated cases of persons who have lived for a hundred years. As Young, former president of the British Actuarial Society, has shown in his interesting book [c] on centenarians, most cases of supposed centenarians are either cases of conscious or unconscious exaggeration or of error in records. For instance, the Countess of Desmond is said to have lived 130 years, owing to the confusion of two persons of the same name, one of whom lived to be 100 years old, while the other, her mother, died at 30, and their lives were combined in subsequent records. There are, however, some authenticated cases. Thus, the Norwegian Drakenberg was born in 1626 and lived until 1772, aged 146. "He was married when 111 years old, and as a widower of 130 proposed to marry again, although without success." [d]

At Portland, Oreg., Mrs. Mary L. Wood died recently at the age of 120 years and under circumstances which permitted the authentication of her case by the Oregon Historical Society. From these and from other cases which might be mentioned, we may conclude that if to-day, notwithstanding all existing chances of death, it is possible for some persons to live beyond 120, the chances in the future for a larger proportion of such persons will be materially improved. Whether this proportion could ever become the major part we have as yet no means of knowing. What is needed is study, and Metchnikoff is right in believing that the study is well worth while from every point of view.

APPENDIX TO CHAPTER XI.—*Method of computing possible prolongation of life.*

SECTION 1.—*"Expectation" at median ages as short cut to average expectations.*

The table given in Chapter XI is briefly described in the chapter itself. The following additional explanations are made in regard to the statistical method employed:

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[a] Metchnikoff, "Prolongation of Life," p. 84.

[b] Shaler, loc. cit., p. 61.

[c] T. E. Young: "Centenarians," London (C. & E. Layton), 1899.

[d] See article by Harald Westergaard, (British) Economic Journal, Vol. IX, 1899, p. 315.

The third column, giving the expectation of life which is lost or cut off by each particular cause of death, is estimated roughly by taking the expectation of life pertaining to the median age reached by those who die from the cause named. This expectation of life is taken from the Massachusetts Life Tables, 1893–1897.[a]

The method of using the median age is sufficiently exact in view of the inexact, or rather, safe, minimum estimates of preventability given in column five. A perfectly correct method would be much more laborious. Hayward's monograph on the effect on the duration of life of eliminatiug only one disease (tuberculosis) requires 190 pages of calculation. The true method consists in averaging arithmetically and weighting these averages according to the number dying at the various ages. Specimen computations show that the error involved by the short cut is not great.

Thus, for tuberculosis it is found that the average expectation of life lost by consumptives dying in 1906 was 32 years, whereas the expectation of life at the median age was 33 years. The former figure is a hundredfold more difficult to compute than the latter. Even the former is not strictly correct, since it applies to the deaths by ages as distributed in 1906, and not as distributed in a "stationary" population.

SECTION 2.—*Basis of estimates of preventability.*

The estimates of preventability given in column 5 need special explanation. In a few cases, these estimates are based on statistical experience.[b]

The great majority of them are based on clinical experience merely, without any exact statistics. They are thus in the nature of expert guesses. The experts in all cases are physicians. I have not entered any estimate of my own, unless item No. 36 might be so designated. This item is the residuum of deaths from unknowu causes, or ill-defined causes, and is made up to a large extent of cases not properly reported in the death certificates. Inasmuch as the average preventability for all other causes in the table is over 42 per cent, it seemed safe to assign to deaths from these unknown causes a ratio of preventability of 30 per cent. But even if the preventability were entered as 0, the effect in reducing the result would be less than a year.

Those who gave to the construction of these estimates the benefit of their experience, observations, and reading were especially asked above all to be conservative. In order to avoid any possibility of exaggeration of their estimates

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[a] S. W. Abbott, M. D.: "The vital statistics of Massachusetts for 1897, from the thirtieth annual report of the state board of health of Massachusetts." The expectation is taken as the average of the expectations for males and females.

[b] In addition to the data in regard to special diseases discussed in the text, other pertinent material has beeu taken into account by those who made the estimates presented in the table. For instance, from smallpox in London in 1901–2 the mortality was 34.6 per cent among the unvaccinated, 20.9 per cent among those vaccinated after the disease was apparent, and 10.3 per cent where there was protective vaccination. In Gloucester in 1895–96 the mortality among the unvaccinated was 40.8 per ceut and amoug the vaccinated 9.8 per cent. For children under 1 year the unvaccinated had a mortality of 72 per cent, while the vaccinated were not attacked. From cerebro-spinal meningitis the average mortality was 70 per cent (Holt); the mortality under serum treatment was 25 per cent (Flexner and Jobling). For typhoid fever, Koch and his assistants stamped out the disease in Trier by isolation of the infected persons and disinfection. (Osler, The Practice of Medicine, sixth edition.) This would probably be impracticable to such au extent in a city on account of the great expense involved and the difficulty of detecting the bacillus carriers. Other figures for typhoid fever are given in the text. For diphtheria in New York City in 1889–1891 we find the mortality was 37.3 per cent, while in 1902–1904 the mortality was 10.8 per cent. The board of health began to use antitoxin in 1895. These facts were furnished by Professor Blumer. Many data on preventability are given by John C. McVail in The Prevention of Infectious Diseases, New York (Macmillan), 1907. See especially pages 16–19. Doctor Stiles, of the Public Health and Marine-Hospital Service, is soon to publish figures showing the absolute preventability of hook-worm disease, a malady prevalent in the South, but not entering into the census tables. These tables do not cover the Southern States.

in the table their average was taken, and then the estimate, as entered in the table, was taken either as that average or below it. In no case was the estimate entered as above the average given. When, as was true in a large proportion of cases, the different estimates agreed fairly well, the average was employed, or rather the nearest figure ending in 0, or 5 next below the average. If the individual estimates diverged widely, an estimate was used below the average, favoring the conservative estimators rather than the optimistic. Also in cases where only a few estimates were obtainable, the estimate as entered was put below the average of those given.

In estimating the percentage of preventability for all the ninety causes of death, 18 estimators contributed. The number of estimates of preventability for each cause averaged nearly eight for each cause of death. It will be seen, therefore, that the table represents in a conservative way medical opinion as to the preventability of disease. The physicians who contributed these estimates are: Dr. Joseph M. Flint, professor of surgery, Yale Medical School; Dr. George Blumer, professor of the theory aud practice of Medicine, Yale Medical School; Dr. H. L. Swain, clinical professor, Yale Medical School; Dr. Oliver T. Osborne, professor of therapeutics, Yale Medical School; Dr. J. H. Townsend, secretary of Connecticut state board of health; Dr. F. W. Wright, health officer of New Haven; Dr. Norman E. Ditman, of Columbia University; Dr. Cressy L. Wilbur, Chief of Division of Vital Statistics, Bureau of the Census; Dr. L. O. Howard, Chief of Bureau of Entomology, Department of Agriculture; Dr. William C. Woodward, chief health officer of District of Columbia; Dr. Charles V. Chapin, city health officer, Providence, R. I.; Dr. Henry B. Baker, ex-secretary Michigan state board of health, ex-president American Public Health Association; Dr. J. H. Kellogg, superintendent of the Battle Creek Sanitarium; Dr. Charles H. Castle, of Cincinnati, Ohio; Dr. Harry M. Steele, of New Haven, Conn.; Dr. L. Emmett Holt, of New York; Dr. Edwin O. Jordan, of the Memorial Institute for Infectious Diseases, Chicago, Ill.; Dr. Prince A. Morrow, president of the American Society for Sanitary and Moral Prophylaxis.

SECTION 3.—*Meaning of "preventable."*

The meaning of the word "preventable" requires some explanation.

1. It is to be noted that column 5 gives the ratio of preventability for mortality and not for morbidity. It means ratio of preventable deaths to all deaths, not to all cases of illness.

2. Since the word "preventable" implies the hypothesis of different conditions from those which actually exist, it is necessary to specify what hypothetical conditions shall be implied in the term. Doubtless tuberculosis would be over 99 per cent preventable if we should conceive as our hypothetical conditions that every individual could live on the prairies of the West, out of doors, be provided with the best of food, most congenial of tasks, and free from overwork and worry. Needless to say, the figures in the table do not imply such Utopian conditions, nor do they imply new medical discoveries. One hundred per cent of every disease might be preventable if we conceived as our hypothesis that the means of prevention are known and applied. The hypothetical condition selected for the meaning of the term "preventable" is contained in the following definition: *A "ratio of preventability" is the fraction of all deaths which would be avoided if knowledge now existing among well-informed men in the medical profession were actually applied in a reasonable way and to a reasonable extent.* The term "reasonable" is of course elastic, and will be somewhat differently interpreted by different persons, but, as in law, where "reasonable care" is often used as a proviso, it is impossible to make any more specific condition.

3. Considerable confusion exists in the minds of many people in regard to the number of deaths which might be prevented, or, as it is popularly expressed, the number of lives which might be saved. Since death is ultimately inevitable for all, no life can be saved except temporarily. It will serve to avoid confusion if "preventable" is explained as "postponable." The question arises when deaths are postponed, How long are they postponed? The answer is, They are supposed to occur according to existing rates of mortality. Thus, those saved from croup (No. 12) at age 2 will later die as do others who are living at age 2, and will therefore have the expectation of life (54 years) pertaining to that age.

4. The above explanation will serve to meet an objection which otherwise would immediately occur to the reader. If diseases of early life are prevented, the result will necessarily be an increase of the diseases in later life. For instance, if all the causes of death could be abolished except old age, there

would be a great increase in the number of deaths from old age, which, instead of constituting the 2 per cent of all deaths, which it does at present, would constitute 100 per cent.

But the fact that all lives saved will add to the later mortality is fully, and more than fully, taken into account in our calculations. When we assume that certain lives now lost at a given age might be saved, we also assume that they would not be saved again (even from the same disease), but would die off according to the old rates of mortality at successive ages. Their new lease of life would simply be the old expectation of life. As a matter of fact, lives now lost could probably be saved, not only once, but several times.

We may here explain the paradox mentioned in the text—namely, that a preventability of 42.3 per cent of deaths under present conditions does not imply that the death rate would ultimately be reduced 42.3 per cent.

The death rate would ultimately depend on conditions of the distribution of ages and diseases entirely different from those now prevailing. This will be clear if we think what would happen if the preventability expressed in the table could be immediately applied. During the ensuing year it would be found that about 42 per cent of present deaths would not occur. A consequence of this, however, would be that the persons whose lives were prolonged would die at a later period, since no death is absolutely prevented, but only postponed. Even if 100 per cent of all deaths were prevented (postponed), but the postponement were for a very short time, the effect in reducing the death rate would be extremely small. On the other hand, if only 1 per cent of the preventable deaths were postponed for a sufficiently long time, the ultimate effect would be to reduce the death rate much more than 1 per cent. After the deaths which had been postponed had reentered, a new equilibrium would be established. Under these new conditions the ratio of the deaths to the population would not be 42.3 per cent lower than at present, but only about 25 per cent. At present the average duration of life, taken from the Massachusetts table for 1893–1897, is about 45 years. The ratio of preventability in the above table would increase this life by about fifteen years, making it 60 years. The ratio of 45 to 60, showing the increase in the life span, will be the inverse of the ratio 60 to 45 in a "stationary" population, which would show the resulting reduction in the death rate. This is a reduction of 25 per cent. Thus the preventability of 42.3 per cent of deaths under present conditions and in the manner indicated in the table involves a lengthening of life of 33⅓ per cent and a reduction of the death rate, after readjustment of deaths by ages, of about 25 per cent.

SECTION 4.—*Error from abnormal age distribution of deaths in 1906.*

The table as given is constructed for deaths occurring in the calendar year 1906. Its interpretation, however, is to be made on the basis of a survivorship table. In a stationary population the age distribution of deaths in any year would be the same as in a survivorship table; but since the United States has not a stationary population, this identity holds only approximately.

The discrepancy accounts for the difference of one and three-tenths years in the prolongation of life, as calculated in the table and by means of the diagram. The latter is the more correct, as it is based on a survivorship table, or—what amounts to the same thing—on such mortality as would exist in a stationary population. The only way in which this diagram can be vitiated by the slightly abnormal age distribution of deaths in the year 1906 is as this abnormal distribution affects the average ratios of preventability used in constructing the diagram. These ratios are based on column (5) of the résumé of the table. The four figures from the table are adjusted by graphic interpolation in the usual way, so as to form a continuously varying series of figures for successive years of life. These ratios are in each case an average of the individual ratios for particular diseases, contained in the same column (5) of the larger table. The "weights" are slightly vitiated by the fact that the age distribution of deaths in 1906 is not the normal distribution of a stationary population. It is only as the "weighting" is thus affected that the diagram can be vitiated through our being forced to use the figures for 1906 instead of those for an ideal stationary population, since such figures are unobtainable. The error from this source is infinitesimal, and we may depend on the results of the diagram, 12.8 to 14.9 years, as practically free from any appreciable error due to the use of short-cut methods.

SECTION 5.—*Ratios of preventability by ages derived from ratios of diseases.*

In regard to the résumé containing the average ratios of preventability holding true during differeut ages, it will be observed that they are obtained indirectly, by calculating from the individual ratios of preventability for different diseases given in the table itself. Although these diseases are not absolutely limited to the times within which their median falls, there is a fairly distinct liue of demarcation between the groups, especially between children's diseases and those of middle life. The table shows no disease with a median age of incidence betweeu 8 aud 23 years, and the census table of deaths for 1906 shows that a very small percentage of the total deaths occur between ages 10 and 20. Even if the diseases cousidered for the four epochs of life given in the résumé did extend somewhat into the regions of the adjacent epochs, the effect would not chauge the result appreciably and would be as likely to change it in one direction as the other. The reason is that the items of the coluum in the résumé for "ratio of preventability" are obtained by dividing the figures in columu 6 by those in column 4, each of these two being found by adding the individual figures in the table for each age group concerned. The extension of diseases of au age group outside of that group will apply equally to both terms of the ratio, those in the fourth and sixth columns, and will not substantially affect the quotient in the fifth column.

SECTION 6.—*Allowance for weakness of prolonged lives.*

The use in column 2 of the expectations of life derived from the Massachusetts 1893–1897 life table is equivalent to the assumption that if preventable deaths were prevented the lives thus saved would proceed to die off according to the mortality of Massachusetts, 1893–1897. This assumes that siuce 1893–1897 there has been no improvement in the expectation of life, and that the saved lives will not share in the improvement which the table itself shows forth. The reason that a later life table than for 1893–1897 was not used is that no later life table is available. If it were, it would show larger figures in column 2, and consequently a larger total result for the possible prolougation of life than fourteen years.

The reason the "expectation" in columu 3 does not take account of the effect of the improvement iu mortality resulting from the table is that this improvemeut can not be calculated until column 3 is filled, and we prefer to use as a first approximation a conservative figure in column 3, rather thau to guess at more likely figures. The conservative assumption used seems also advisable, because of the fact that in the 42.3 per ceut of persons in the life table who would be saved from death and given a new lease of life there would be suffered a greater mortality than that of the average persons that now pass that age in safety, for—on the principle of the survival of the fittest—it is intrinsically probable that those who now die at any age are weaker than those who do not.

How much allowance should be made for this factor of differential mortality it is impossible to say with certainty. But in another paper [a] I have dealt with the same question applied to tuberculosis. Taking the figures of Dr. Lawrason Brown, giving the mortality experieuce among the apparently cured cases of tuberculosis discharged from the Adirondack Cottage Sauitarium, and making certain allowances, it seems that if tuberculosis were prevented its preseut victims would have more than three-fourths of the expectation of life belonging to others. Let us assume that this ratio is equally couservative as applied to all other cases of prolongable life. Now, it so happens that the expectatiou of life at birth in the Massachusetts life table of 1893–1897 is almost exactly three-fourths of the expectation which our table and diagram shows would be possible if prevention were properly practiced. This would give 45 years as the expectation of life at birth for the saved lives, 61 for other lives, and 59 for all lives. Surely this seems sufficieut allowance for the existence of any possible inferiority among the lives which would be saved.

SECTION 7.—*Diagram "Possible I," making this allowance, compared with "Possible II," omitting it.*

If no allowance for inferiority among saved lives were necessary, the results of the calculation given in the table would be only a first approximation and

[a] "The cost of tuberculosis in the United States and its reductiou," read before the International Congress on Tuberculosis, 1908.

would need to be followed by successive and closer approximations. We can get much quicker results by means of the diagram and a planimeter.

If we apply the ratios of preventability for these four groups, we are able to construct the new survivorship table on the basis of Mr. Abbott's for 1893–1897. All that is necessary is to begin the new survivorship table at the same point that the old begins, and continue from that point and every other point throughout its course by the following procedure: Through the point draw a line downward and to the right for one year, at the same percentage slope as Abbott's table shows for that year. This line indicates what survivors there would be if their mortality were not affected at all by the ratio of preventability. The deaths during that year would be represented by the drop of the curve within the year. Next, taking the proper fraction of this drop, as indicated by the ratio of preventability, we pass vertically upward this amount from the end of the line, and from the new point so obtained proceed in like manuer for each subsequent year. The result is a series of teeth the upper points of which are points on the required curve. Joining these points, we obtain the curve. This process explains the theory. This gives the table called "Possible I," and takes full account of the fact that the ratios of preventability continue to apply to saved life as much as to other life. The table "Possible I" represents the survivorship table, under the assumption that the lives saved once are given no further advantages, but follow thereafter the old law of mortality, that for 1893–1897.

SECTION 8.—*Reciprocal relation between longevity and mortality shown by diagram.*

We may take this opportunity to explain, for the benefit of the general reader, the reciprocal relations existing between the death rate in a stationary population and the average duration of life. Consider the diagram "Massachusetts, 1893–1897." It shows the life history of 100,000 persons born. Let us suppose a community unaffected by emigration or immigration, and in which there are 100,000 births each year. Let us suppose, further, that the 100,000 persons born each year die afterwards according to the law of mortality represented by the curve "Massachusetts, 1893–1897." Evidently in such a community there will not only be 100,000 births, but there will be 100,000 deaths each year, and the population will be stationary. It will also be true that the same diagram can be taken to represent the age distribution of this stationary population. Thus, those living at age 10 will be the survivors of the 100,000 born ten years ago, and the number of such survivors is the ordinate of the curve at 10 years. Thus, every ordinate of the curve represents not only the survivors to a certain age out of 100,000 births, but also represents the number in the population at that age. The area of the curve therefore represents total population (when regarded as made up of vertical sections). It likewise represents the total number of years lived by 100,000 persons (when regarded as made up of horizontal sections). Now, the death rate is the ratio of deaths to population—i. e., the ratio of 100,000 to the area of the curve. The average duration of life is the total years lived by 100,000 persons divided by 100,000—that is, it is the area of the curve divided by 100,000. These are clearly reciprocals.

CHAPTER XII.—*The money value of increased vitality.*

SECTION 1.—*Money appraisal of preventable wastes.*

Estimates of the money value of preventable wastes depend on the valuation of *human life*, of which several appraisals have been attempted.

Prof. J. S. Nicholson estimated that in Great Britain human labor capitalized was worth five times all other capital.[a]

Engel computed that each child costs 100 marks at birth, 110 marks the first year, 120 the second, and so on. At 20 he will have cost 2,310 marks, or $560. But one-half die before 20. Hence each person who reaches the age of 20 actually costs society much more than $560; possibly as high as $1,000, if Engel's estimates are correct. Professor Mayo-Smith estimated that men and women between the

[a] See "The Living Capital of the United Kingdom" (British) Economic Journal, 1891.

ages of 15 and 45 averaged $1,000 in value.[a] As to the value of immigrants to this country, he says: "Every immigrant must represent labor value with at least the value of a slave. It is figured that each immigrant is worth $875."[b]

The best method of estimating the economic value of life and its increased duration is by the capitalization of earning power. Dr. William Farr, of England, has estimated that a baby born to an English agricultural laborer is worth in capitalized earning power about £5, or $25. This is the discounted value of its future earnings estimated on its probable life less the discounted value of the cost of rearing it during the period of dependence and of maintaining it when helpless through old age. In the same way he estimates the value of a life at other ages—10 years, 20 years, 50 years, etc.[c]

In lieu of any estimates for the United States we may take Farr's figures for agricultural laborers as representing, roughly, the relative worth of a man or woman in the United States. To obtain the absolute figures, therefore, we need simply to multiply these of Farr by a constant factor representing the ratio between the average earnings in the United States and the earnings which Farr uses as the yearly income of an agricultural laborer.

We take, in the absence of any good statistics, $700 per annum as a guess, but a safe minimum[d] for the average earnings of workers of all grades, from day laborers to railroad presidents. This assumes that all of the working years are actually employed in work. But since about one-fourth of the persons of working age are not workers, but are supported (for the most part) by earnings of capital, the average should be cut down to three-fourths of this figure, or $525.

Substituting this figure for the £31 in Farr's table, we can reconstruct it to represent the minimum worth of the average American life at different ages. The following figures are taken from the table thus computed:

Age.	Net worth of a person, in dollars.	Age.	Net worth of a person, in dollars.
0	90	30	4,100
5	950	50	2,900
10	2,000	80	−700
20	4,000		

From the table from which these figures are taken it is possible to base minimum estimates for (1) the average economic value of the inhabitants of the United States by using the census figures for age

[a] Mayo-Smith, Statistics and Sociology, p. 177.
[b] Mayo-Smith, Emigration and Immigration.
[c] See Farr, "Vital Statistics," p. 536.
[d] See Fisher "Cost of tuberculosis," read before the International Congress on Tuberculosis, Washington, 1908. This is the estimated minimum used in my paper on the "Cost of tuberculosis." The calculations are based on $1 a day as the ordinary minimum earnings of unskilled labor, and assume a distribution of a number of earners of high amounts accordiug to the scale of distribution which Professor Pareto finds fairly uniform in form, although not in amount in various countries. The late honorable Carroll D. Wright, whose opinion is worth more, probably, than that of any other man in the United States, stated that he would not regard $1,000 as excessive. The figure is intended to include the earnings of women (including housewives as earners).

distribution of population; this calculated average is $2,900; (2) the average economic value of the lives now sacrificed by preventable deaths, using the age distribution of deaths, and the percentages of preventability; this calculated average is $1,700.

The first figure shows that what might be called the vital assets of the United States for the population of over 85,500,000, as estimated by the census of 1907, amount in value to 85,500,000×$2,900, or $250,000,000,000, which, though a minimum estimate, greatly exceeds the value of all other wealth;[a] the second figure enables us to estimate the needless waste of our vital assets.

If we take the estimate of Professor Willcox of the death rate in the United States, as at least 18 per 1,000 for the 85,500,000 persons estimated by the census as the population of the United States in 1907, we have 1,500,000 as the number of deaths in the United States per annum. Of these 1,500,000 deaths, 42 per cent, or 630,000, are annually preventable or postponable. Since each postponement would save on the average $1,700, the national annual unnecessary loss of capitalized net earnings is 630,000×$1,700, or $1,070,000,000, or about $1,000,000,000.

We saw in Chapter III that, with our present population, there are always about 3,000,000 persons in the United States on the sick list. For the most part these persons are older than the average. Farr gives a table[b] showing that morbidity increases with age in geometric progression. By means of his table we may calculate on the same basis as the previous calculations—that of the 3,000,000 sick, very close to a third, or 1,000,000 persons, are in the working period of life. Assuming that average earnings in the working period are $700, and that only three-fourths of the one million potential workers would be occupied, we find over $500,000,000 as the minimum loss of earnings.

The cost of medical attendance, medicine, nursing, etc., is conjectured by Doctor Biggs in New York to average for the consumptive poor at least $1.50 per day of illness. The cost per day of other illnesses than tuberculosis is presumably greater, and also the cost per day for other classes is higher than for the poor. Applying this to the 3,000,000 years of illness annually experienced, we should have $1,500,000,000 in all as the minimum annual cost of this kind.

The statistics of the Commissioner of Labor[c] show that the average expenditure for illness and death amount to $27 per annum. This is for workingmen's families only. But even this figure, if applied to the 17,000,000 families of the United States, would make the total bill for caring for illness and death $460,000,000. The true cost may well be more than twice this sum. Certainly this estimate is more than safe and is only one-third of the sum obtained by using Doctor Biggs's estimate.

The sum of the costs of illness, including loss of wages and cost of care, is thus $460,000,000+$500,000,000, or $960,000,000.

The above estimate is a general one for all illness. It would be possible to offer figures for the particular losses from particular dis-

[a] Mr. Le Grand Powers, of the Bureau of the Census, Washington, estimates that the total wealth in America (exclusive of human beings) amounts to $107,000,000,000.

[b] Vital Statistics, p. 510.

[c] Eighteenth Annual Report, 1903, p. 509.

eases. Thus, from tuberculosis, the gross loss of earnings by illness and of potential earnings cut off by death, together with the expenses of illness, etc., amount to over $1,000,000,000 per annum.[a]

Of the sum mentioned, the loss to the consumptives themselves amounts to over $660,000,000, leaving $440,000,000 as the loss to other members of the community. At least three-fourths of these costs are preventable. Dr. George M. Kober thinks it is conservative to say that the annual cost of typhoid in the United States is $350,000,000[b] and Dr. L. O. Howard believes that malaria alone costs the country $100,000,000 annually, and the insect diseases generally $200,000,000.[c] He points out that one great item of loss is the reduced value of real estate in malarial regions. By drainage and destruction of mosquitoes most of this waste could be saved. The cost of the care of the insane and feeble-minded is estimated by Charles L. Dana at $85,000,000 annually.[d] What fraction of these costs is preventable it is difficult to say. The economic loss due to alcohol has been variously estimated.[e] Of the billion dollars or more found to represent the cost of illness, by far the major part is certainly avoidable. This is the belief of the best observers, such as Doctor Gulick, Doctor Kellogg, Mrs. Richards, Doctor Anderson, and others. Unfortunately there are no exact statistics of preventability. We feel safe, however, in concluding that at least half a billion could be saved from the present cost of illness. This, added to the loss by preventable deaths of potential earnings of a billion, gives at least a billion and a half of preventable waste. This does not include the losses from inefficient work due to drunkenness or other vicious habits; nor does it include the cost of "undue fatigue," which we have some reason to believe exceeds in its effect on efficiency the loss from illness. But it would not be possible to state this loss in any definite or convincing figures.

The actual economic saving annually possible in this country by preventing needless deaths, needless illness (serious and minor), and needless fatigue, is certainly far greater than one and a half billions, and may be three or more times as great.

Dr. George M. Gould estimated that sickness and death in the United States cost $3,000,000,000 annually, of which at least a third is regarded as preventable.[f]

> The trouble is the public does not believe in this waste from being "just poorly," and "so as to be about." It has no conception of the difference between working with a clear brain and steady hand and with a dull and nerveless tool. They must be convinced somehow.[g]

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[a] See Irving Fisher: "Cost of Tuberculosis in the United States, and its Reduction."

[b] See his "Conservation of life and health by improved water supply," read before the White House Conference of Governors, 1908.

[c] Report to Conservation Commission on "Economic loss to the people of the United States through insects that carry disease."

[d] See "Psychiatry in its relation to other sciences," by Charles L. Dana, before the section on psychiatry at the International Congress of Arts and Sciences, St. Louis, September, 1904.

[e] "Economic aspects of the liquor problem." An investigation made for the Committee of Fifty, under the direction of Henry W. Farnam, secretary of the economic subcommittee, 1899, 327 pages.

[f] "Disease and Sin," American Medical Journal, August 31 and September 7, 1901.

[g] Letter from Ellen H. Richards.

SECTION 2.—*The cost of conservation.*

It costs no more to "raise" a man capable of living for 80 years than it does to "grow" one who has not the capacity of living to be 40 years old.[a]

We have seen how much potential value of life is now allowed to be wasted which could be prevented. But the question remains, What would it cost to conserve it? It is, of course, not possible to answer this question definitely and fully. The best we can do is to point out specific instances of the health returns which follow on investments in the improvement of vital conditions.

The following examples will show the returns which may be expected from well-planned expenditures on behalf of public health:

The city of Pittsburg is just iustalling a great municipal filter plaut for the purification of its principal water supply, at an expense of upward of $7,000,000. It is reasonable to estimate that in a year or two this should effect a saving of 100 deaths a year from typhoid fever, for the uumber of typhoid-fever deaths of late years has been 400 or more yearly. Valuing these lives at $5,000 each, as is customary, the saving effected by the purification works should be half a million dollars' worth of human life annually, making the building of the filter a sound and profitable economic as well as humanitarian measure. But if, as Mr. MacNutt and I have shown, Hazen's theorem is true, then for every 100 deaths saved from typhoid fever at least 200 will be saved from other causes, which means at least $1,000,000 more saved to the city of Pittsburg annually of its present waste of humau life.[b]

England reckons that the lives saved through the lowered death rate, from what it was between 1866 and 1875 to what it became in the period reaching from 1880 to 1889, amounted to 858,804. This represents on the English basis of the per capita valuation of each life ($770) a social capital of $650,000,000 saved. In ten years Eugland has more than regained the sum spent in fifteen years for sanitary improvements, though the average annual expenditure has been $42,000,000.[c]

The achievement of Huddersfield, Englaud, is especially noteworthy. The average number of deaths of infants for ten years had been 310. By a systematic education of mothers the number was in 1907 reduced to 212. The cost of saving these 98 lives was about $2,000.[d]

A saving of infant life is recorded by Doctor Chapin in Providence:

We attempted for two years to distribute clean milk to the babies of the poor, but this year we decided that the mouey could better be spent on trained nurses. Thus far we have expeuded about $900 for this purpose. Two hundred and thirty-five sick children, of whom very many were very sick, have been cared for. Of these only 20 have died. From a study of our statistics I should judge that the reduction in infant mortality effected by the nurses was at least 25 deaths, and it may be that as many as 40 lives were saved.[e]

At the funeral of Maj. Walter Reed, the man who did so much to prove the correctness of Doctor Finley's discovery that the mosquito is the carrying agent for the yellow-fever germ, Gen. Leonard Wood

[a] T. S. Lambert: "Sources of Longevity," New York, 1869, p. 6.

[b] W. T. Sedgwick: "The call to public health," Science, 1908, p. 198.

Since the foregoing was written, there has appeared in "Charities," February 6, 1909, "Thirty Five Years of Typhoid" by Frank E. Wing, in which it is shown that there were in 1907, in Pittsburg, 4,921 cases of typhoid, of which 622 died; and that the cost per patient, irrespective of the lives lost, was $128, making the cost for the city $694,000. Reckoning $4,000 as the value of each life lost, the total annual money cost from typhoid in Pittsburg is over $3,000,000, and, according to Hazen's theorem, already meutioned, this is probably not one-half nor even one-third of the total.

[c] Ditman, loc. cit., p. 4. Taken from M. G. Dana: "Results of municipal sanitation," Annals of Hygiene, 1896, Vol. II, p. 391.

[d] Letter from Dr. Charles V. Chapin.

[e] Ibid.

declared that this discovery is saving more lives annually than were lost in the Cuban war, and that it is saving the commercial interests of the world a greater financial loss each year than the cost of the entire Cuban war.[a]

As to what the stamping out of yellow fever means, in money terms, the following is significant:

> It has been estimated that the yellow fever epidemic of 1878 invaded 132 towns, caused a mortality of 15,954 persons, and that the pecuniary loss to the country was not less than $100,000,000 in gold.[b]

The economic loss to Philadelphia, caused by the smallpox epidemic of 1871–72 has been estimated by Doctor Lee at $22,000,000. This includes loss to travel and traffic on railroads, loss to hotel keepers, merchants, and manufacturers, cost of care of sick, loss of time, and the expense of burial. A vaccine bureau with physicians, a disinfecting station, and the inauguration of a campaign of education capable of forestalling the whole epidemic would have cost $700,000.[c]

It is reported that San Francisco plans an investment of $30,000,000 in stone and concrete quays to prevent rodents from infecting the city, and this is regarded by experts as worth while many times over.

In respect to hook-worm disease, rating the earning per diem of the southern farm laborer at 75 cents, 28 observers report that average laborers infected with hook-worms earn 40 cents per diem. Ten observers having cotton-mill practice report unanimously that the disease is very prevalent among cotton-mill laborers, and rating the average mill laborers at $1.50 per diem, they consider 75 cents as a fair rating for hook-worm bearing laborers.[d]

> It would be difficult to even roughly estimate the cost of this disease to the South, but from what we know of it in this State I would say that it costs South Carolina not less than $30,000,000 per year, and this inability to perform regular and efficient labor is the smallest part of the cost.[e]

It has been figured that the hook-worm disease of the South could be wiped out within a generation[f] through the expenditure of from one to two millions of dollars by federal and state agencies. It costs about 15 to 75 cents (wholesale) for drugs to cure a case of hook worms. In three months the quantity of red corpuscles in the blood can easily be increased 10 to 50 per cent, according to the severity of the case, and the[g] absenteeism of the victims could easily be reduced 25 per cent.

> Another noteworthy result of well-directed sanitary effort is the reduction of hook-worm disease in Porto Rico. As you are doubtless aware, this disease causes a tremendous lowering of the physical efficiency of the people of that island. As you may see by the report of the special commission for 1906 and 1907 made to Governor Post, 89,000 people were treated, and for the most part cured, for 54 cents each.[h]

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[a] Ditman, loc. cit., p. 12.

[b] Walter Wyman, M. D., "Quarantine and Commerce," address before Cincinnati Commercial Club, October 15, 1898, p. 8.

[c] Ditman, loc. cit., pp. 8–10, from Bissell, A Manual of Hygiene.

[d] Letter from Dr. W. J. Burdell.

[e] William Weston, "Uncinariasis," South Carolina Medical Association, 1908, p. 8.

[f] Dr. Charles W. Stiles, of the United States Public Health and Marine-Hospital Service, who has studied the hook-worm disease more thoroughly than any one in the country.

[g] Letter from Doctor Stiles.

[h] Letter from Charles V. Chapin, 1908.

Medical inspection in our schools also returns large dividends on small investments.

Using these data as a basis, we have the annual expenditure for medical inspection of $345,135 in those cities from which we have succeeded in obtaining data. It seems probable, although this is frankly a guess, that the total annual expenditure for medical inspection of schools in the United States at the present time is perhaps $500,000.[a]

The money saved by enabling thousands of children to do one year's work in one year, instead of in two or three years, would greatly exceed the total expense of examining all school children in all boroughs.[b]

Doctor Jessen has shown that the cost of a school dental clinic in Germany is only one mark per year per child.[c] The cost saved must be very many times this sum. Dr. Herbert L. Wheeler, of New York, estimates that the Children's Aid Dental Clinic in New York cost $342 for the last fiscal year (35 cents per operation and 70 cents per child treated). He reckons that the neglect of these slight repairs would later have cost far more in dentistry, as well as over $2,000 worth of lost time. These losses are of course of minor importance compared with the pain, inconvenience, and secondary effects on health and efficiency which are inevitably associated with bad teeth.

Mr. Edwin Chadwick, who was once secretary of the English National Board of Health, stated that a sanitary "engineer ought to contract for the reduction of the sickness and death rate, in such a city as Glasgow, by at least one-third, for a penny a head of the entire population."[d]

It is necessary, if we are to do our utmost, to spend a thousand pounds of public money on this task where we now spend one pound. It would be reasonable and wise to expend ten million pounds a year of our revenues on the investigation and attempt to destroy disease. Actually what is so spent is a mere nothing, a few thousands a year. Meanwhile our people are dying by thousands of preventable disease.[e]

Mr. Hiram J. Messenger, actuary of the Travelers Insurance Company, of Hartford, has constructed and sent me a table showing that life insurance companies could probably make money now by taking a hand in the public-health movement, with the purely commercial object of reducing their death losses. He says:

This table shows that if the companies were to expend $200,000 a year for this purpose and as a result should decrease their losses by the almost insignificant amount of twelve one-hundredths of 1 per cent, they would save enough to cover the expense. If such a plan as this were placed on a purely scientific basis and carried out by good business methods and all the companies pulled together for the common good, I should expect a decrease in death claims of more than 1 per cent. And a decrease in death claims of 1 per cent would mean that the companies would save more than eight times as much as they expended or would make a net saving of more than seven times the expense—which would be about a million and a half dollars a year.

The examples given show tangible returns on the investment of several thousand per cent as a rule. While it would be impossible to

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[a] Letter from Dr. Luther H. Gulick.

[b] Sixty-third Annual Report of the Association for Improving the Condition of the Poor, New York, 1906.

[c] See "Jahresbericht der Städtischen Schulzahnklinik in Strassburg," in Odontologische Blätter 12, No. 15–16, 1907.

[d] Transactions of the British Social Science Association, 1866, p. 580. Quoted by Dr. Edward Jarvis, Political Economy of Health, Fifth Report, Mass. Board of Health, 1874, p. 367.

[e] E. Ray Lankester, "The Kingdom of Man," New York (Holt), 1907, p. 148.

state in general terms how rich a return lies ready for public or private investments in good health, the foregoing examples and numerous others show that the rate of this return is quite beyond the dreams of avarice. Were it possible for the public to realize this fact, motives both of economy and of humanity would dictate immediate and generous expenditure of public moneys for improving the air we breathe, the water we drink, and the food we eat, as well as for eliminating the dangers to life and limb which now surround us.

CHAPTER XIII.—*The general value of increased vitality.*

SECTION 1.—*Disease, poverty, and crime.*

In the preceding chapter we have attempted to estimate in money the preventable wastes from disease and death. Although the figures for national losses strike the popular imagination, they have little significance; in fact, money estimates in this field, even when made on the per capita basis, are of little value except as emphasizing the overwhelming importance of human vitality compared with those interests which are usually measured in money. It is impossible in any true sense to measure human life in terms of dollars and cents.[a] The measure of life may perhaps be found in happiness, or the satisfactions enjoyed between birth and death, less the dissatisfactions.

Is life worth living? has been a much asked question, especially since Mr. Mallock wrote a book with that title. The witticism sometimes given in answer, "That depends upon the liver," is true in both of its two meanings. A life of happiness is always worth living, and a life of usefulness, which brings happiness to others, is doubly worth living.

It is hardly necessary to recount all the conditions which tend to produce happiness. No one would question that the most fundamental condition of all is health, in spite of exceptional cases in which unhealthy people are found happy, and healthy people unhappy. It would be impossible to express in exact terms the extent to which improved health could increase human happiness; but every observer of human misery among the poor reports that disease plays the leading rôle. Students of criminology and vice agree that these are chiefly the result of morbid conditions and habits. Health reform brings in its train great and lasting reductions in poverty, criminality, and vice.

We began this report by showing the relation between the conservation of health and the conservation of wealth. The broadest view of this relation is, as Emerson has said, that "Health is the first wealth," and as such it is treated by many economists.[b]

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[a] Even as a measure of what economists call "utility," a money estimate is misleading, for the reason that the "marginal utility" of money varies with different persons. For instance, a week's wages of $10 lost to a poor wage-earner is in such an estimate counted on a par with an expenditure of $10 by a wealthy invalid for a dainty morsel of food, although the loss in "utility" to the former is vastly greater than that to the latter.

[b] Among those who have included health in the category of wealth are Davenant, Petty, Canard, Say, McCullough, Roscher, Wittstein, Walras, Engel, Weiss, Dargun, Ofner, Nicholson, and Pareto. See Irving Fisher: "The Nature of Capital and Income," New York (Macmillan), 1906, p. 5.

Without enlarging or insisting upon this concept, it is obvious that by the conservation of health we may ultimately save billions of dollars of wasted values, and that this conservation is intimately related to conservation of all other kinds.[a]

We have already seen the vicious circle set up between poverty and disease, each of which tends to produce the other. Metchnikoff[b] contends that health and morality are correlative, if not interchangeable, terms. A similar idea has been elaborated statistically by Dr. George M. Gould.[c] The subject is worth much further study. National efficiency is crippled by any one or all of the parts of the vicious circle—disease, poverty, vice, vagabondage, crime. It would be interesting to study the tramp problem, which represents an enormous waste of labor power, in relation to all these phenomena.

SECTION 2.—*Conservation of natural resources.*

It is also true that health begets wealth, and vice versa. Whatever diminishes poverty or increases the physical means of welfare has the improvement of health as one of its first and most evident effects. Therefore an important method of maintaining vital efficiency is to conserve our natural resources—our land, our raw materials, our forests, and our water. Only in this way can we obtain food, clothing, shelter, and the other means of maintaining life. Conversely, the conservation of health will tend in several ways to the conservation of wealth. First of all, the more vigorous and long-lived the race, the better utilization can it make of its natural resources. The labor power of such a race is greater, more intense, more intelligent, and more inventive.

The development of our natural resources in the future will be more dependent on technical invention[d] than upon the mere abundance of materials.

Just as in warfare it is not so much the gun as the man behind the gun that makes for success, so in industry, as Doctor Shadwell[e] has shown, skill, knowledge, and inventiveness are the chief factors in determining commercial success and supremacy. The backward nations, like China, are characterized by lack of modern inventions. The nations which are industrially most advanced have the railway, the steamship, the power loom, metal working, and innumerable arts and crafts. The change of Japan from a backward to a forward nation is at bottom the introduction of inventions. If conservation prevents lessened fertility, invention makes two blades of grass grow where one grew before.

Future industrial competition will be increasingly a contest of invention. The world rivalry to develop the best system of wireless telegraphy or the best airships is but one example. The future will see the greatest strides taken by the nation which is the most invent-

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[a] See Edward Devine, "Efficiency and Relief," New York (Macmillan), 1906.

[b] Prolongation of Life, p. 318.

[c] "Disease and sin," American Medical Journal, Aug. 31 and Sept. 7, 1901.

[d] Since the above was written, President Charles S. Howe, of Cleveland, has presented this point in detail. See "The function of the engineer in the conservation of the natural resources of the country," Science, Oct. 23, 1908.

[e] Arthur Shadwell in his admirable "Industrial Efficiency" (2 vols.). London (Longmans), 1906.

ive. Now, the primary condition of invention is vitality, a clear brain in a normal body. It is no accident that Edison is a health culturist, or that Krupp, Westinghouse, and other pioneers in industrial development have been men of vigor of mind and body.

Finally, the conservation of health will promote the conservation of other resources by keeping and strengthening the faculty of foresight. One cause of poverty in the individual and the nation is lack of forethought.[a]

One of the first symptoms of racial degeneracy is decay of foresight. Normal, healthy men care for and provide for their descendants. A normal, healthy race of men, and such alone, will enact the laws or develop the public sentiment needed to conserve natural resources for generations yet unborn. When in Rome foresight was lost, care for future generations practically ceased. Physical degeneracy brought with it moral and intellectual degeneracy. Instead of conserving their resources the spendthrift Romans, from the emperor down, began to feed on their colonies and to eat up their capital. Instead of building new structures they used their old coliseum as a quarry and a metal mine.[b]

The problem of the conservation of our natural resources is therefore not a series of independent problems, but a coherent all-embracing whole. If our nation cares to make any provision for its grandchildren and its grandchildren's grandchildren, this provision must include conservation in all its branches—but above all, the conservation of the racial stock itself.

Chapter XIV.—*Things which need to be done.*

Section 1.—*Enumeration of principal measures.*

In order that American vitality may reach its maximum development, many things need to be done. Among them are the following:

1. The National Government, the States, and the municipalities should steadfastly devote their energies and resources to the protection of the people from disease. Such protection is quite as properly a governmental function as is protection from foreign invasion, from criminals, or from fire. It is both bad policy and bad economy to leave this work mainly to the weak and spasmodic efforts of charity, or to the philanthropy of physicians.

2. The National Government should exercise at least three public health functions: First, investigation; second, the dissemination of information; third, administration.

It should remove the reproach that more pains are now taken to protect the health of farm cattle than of human beings. It should provide more and greater laboratories for research in preventive medicine and public hygiene. Provision should also be made for better and more universal vital statistics, without which it is impossible to know the exact conditions in an epidemic, or, in general, the sanitary or insanitary conditions in any part of the country.

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[a] See Irving Fisher: "The Rate of Interest," New York (Macmillan), 1907.

[b] See John Rae: "Sociological Theory of Capital," edited by Prof. C. W. Mixter, New York (Macmillan), 1905.

It should aim, as should state and municipal legislation, to procure adequate registration of births, statistics of which are at present lacking throughout the United States.

The National Government should prevent transportation of disease from State to State in the same way as it now provides for foreign quarantine and the protection of the nation from the importation of disease by foreign immigrants. It should provide for the protection of the passenger in interstate railway travel from infection by his fellow-passengers and from insanitary conditions in sleeping cars, etc.

It should enact suitable legislation providing against pollution of interstate streams.

It should provide for the dissemination of information in regard to the prevention of tuberculosis and other diseases, the dangers of impure air, impure foods, impure milk, imperfect sanitation, ventilation, etc. Just as now the Department of Agriculture supplies specific information to the farmer in respect to raising crops or live stock, so should one of the departments, devoted principally to health and education, be able to provide every health officer, school-teacher, employer, physician, and private family with specific information in regard to public, domestic, and personal hygiene.

It should provide for making the national capital into a model sanitary city, free from insanitary tenements and workshops, air pollution, water pollution, food pollution, etc., with a rate of death and a rate of illness among infants and among the population generally so low and so free from epidemics of typhoid or other diseases as will arouse the attention of the entire country and the world.

There should be a constant adaptation of the pure-food laws to changing conditions. Meat inspection and other inspection should be so arranged as to protect not only foreigners, but our own citizens. The existing health agencies of the Government should be concentrated in one department, better coordinated, and given more powers and appropriations.

3. State boards of health and state legislation should provide for the regulation of labor of women, should make physiological conditions for women's work and prevent their employment before and after childbirth; should regulate the age at which children shall be employed, make reasonable regulations in regard to hours of labor and against the dangers in hazardous trades, and especially against the particular dangers of dust and poisonous chemicals; should make regulations for sanitation and provide inspection of factories, schools, asylums, prisons, and other public institutions. Where municipalities have not the powers to enact the legislation above mentioned with reference to local conditions, the necessary legislation or authority should be provided by the State. Or where by reason of the small size of the town no efficient local action is possible, the State should exercise the necessary functions. It should in such cases advise and supervise local boards of health. It should have an engineering department and advise regarding the construction of sewers and water supplies. Pollution of such supplies, unless entirely local, should be prevented by the State, which should be equipped with laboratories for the analysis of water, milk, and other foods. Suitable legislation should be passed regulating the sale of drugs, especially preparations

containing cocaine, opium, or alcohol. Legislation—not too far in advance of public sentiment needed to enforce it—should be passed regulating the sale of alcoholic beverages. State registration of births, deaths, and cases of illness should be much more general and efficient than at present.

4. Municipal boards of health need to have more powers and greater appropriations; less political interference and better trained health officers; more support in public opinion. Their ordinances in regard to expectoration, notification of infectious disease, etc., should be better enforced by the police departments.

More legislation should be advocated, passed, and enforced to the end that streets may be kept clean, garbage properly removed, sewage properly disposed of, air pollution of all kinds prevented, whether by smoke, street dust, noxious gases, or any other source. Noises also should be lessened.

Municipalities need also to take measures to prevent infection being carried by flies, mosquitoes, other insects and vermin, and by prostitution. They need to guard with greater care the water supply, and in many cases to filter it; they should make standards for milk purity and enforce them; they should also regularly inspect other foods exposed for sale; provide for sanitary inspection of local slaughter-houses, dairies, shops, lodging and boarding houses, and other establishments within the power of the particular municipality; they should make and enforce stricter building laws, especially as relating to tenements, to the end that dark-room tenements may be eliminated and all tenements be provided with certain minimum standard requirements as to light, air, and sanitary arrangements.

5. School children should be medically inspected and school hygiene universally practiced. This involves better protection against school epidemics, better ventilation, light, and cleanliness of the schoolroom, the discovery and correction of adenoids, eye strain, and nervous strain generally, and the provision for playgrounds. Sound scientific hygiene should be taught in all schools, public, private, normal, and technical, as also in colleges and universities.

6. The curricula of medical schools should be rearranged with a greater emphasis on prevention and on the training of health officers. Sanatoria and hospitals, dispensaries, district nursing, tuberculosis classes, and other semipublic institutions should be increased in number and improved in quality. The medical profession, keeping pace with these changes, should be the chief means of conveying their benefits to the public. Universities and research institutions need to take up the study of hygiene in all its branches. Now that the diseases of childhood are receiving attention, the next step should be to study the diseases of middle life. These are diseases, to a large extent, of nutrition and circulation, and consequently these subjects should receive special attention. Intelligent action must rest on knowledge, and knowledge of preventing disease is as yet extremely imperfect.

7. In industrial and commercial establishments employers may greatly aid the health movement, and in many cases make their philanthropy self-supporting by providing social secretaries, lunch and rest rooms, physiological (generally shorter) hours of work, provision for innocent amusements, seats for women, etc.

Life insurance companies could properly and with much profit club together to instruct their risks in self-care and secure general legislation and enforcement of legislation in behalf of public health.

8. The present striking change in personal habits of living should be carried out to its logical conclusion until the health ideals and the ideals of athletic training shall become universal. This change involves a quiet revolution in habits of living, a more intelligent utilization of one's environment, especially in regard to the condition of the air in our houses, the character of the clothes we wear, of the site and architecture of the dwelling with respect to sunlight, soil, ventilation, and sanitation, the character of food, its cooking, the use of alcohol, tobacco, and drugs, and last, but not least, sex hygiene in all its bearings.

9. The fight against disease will aid in the fight against pauperism and crime. It is also true that any measures which tend to eliminate poverty, vice, and crime will tend to improve sanitary conditions.

10. Finally, eugenics, or hygiene for future generations, should be studied and gradually put in practice. This involves the prohibition of flagrant cases of marriages of the unfit, such as syphilitics, the insane, feeble-minded, epileptics, paupers, or criminals, etc. The example of Indiana in this regard should be considered and followed by other States, as also in regard to the unsexing of rapists, criminals, idiots, and degenerates generally. A public opinion should be aroused which will not only encourage healthy and discountenance degenerate marriages, but will become so embedded in the minds of the rising generation as will unconsciously, but powerfully, affect their marriage choices.

ECONOMIC LOSS TO THE PEOPLE THROUGH INSECTS THAT CARRY DISEASE.

By L. O. Howard, Ph. D.,
Chief Bureau of Entomology, United States Department of Agriculture.

It has been definitely proven and is now generally accepted that malaria in its different forms is disseminated among individuals of the human species by mosquitoes of the genus *Anopheles*, and that the malarial organism gains entrance to the human system, so far as known, only by the bite of mosquitoes of this genus. It has been proven with equal definiteness, and has also become generally accepted, that yellow fever is disseminated by the bite of a mosquito known as *Stegomyia calopus* (possibly by the bites of other mosquitoes of the same genus), and so far as has been discovered this disease is disseminated only in this way. Further, it has been scientifically demonstrated that the common house fly is an active agent in the dissemination of typhoid fever, Asiatic cholera, and other intestinal diseases by carrying the causative organisms of these diseases from the excreta of patients to the food supply of healthy individuals; and that certain species of fleas are the active agents in the conveyance of bubonic plague. Moreover, the tropical disease known as "filariasis" is transmitted by a species of mosquito. Furthermore, it is known that the so-called "spotted fever" of the northern Rocky Mountain regions is carried by a species of tick; and it has been demonstrated that certain blood diseases may be carried by several species of biting insects. The purulent ophthalmia of the Nile Basin is carried by the house fly. A similar disease in the Fiji Islands is conveyed by the same insect. Pink eye in the southern United States is carried by minute flies of the genus *Hippelates*. The house fly has been shown to be a minor factor in the spread of tuberculosis. The bedbug has been connected with the dissemination of several diseases. Certain biting flies carry the sleeping sickness of Africa. A number of dangerous diseases of domestic animals are conveyed by insects. The literature of the whole subject has grown enormously during the past few years, and the economic loss to the human species through these insects is tremendous. At the same time this loss is entirely unnecessary; the diseases in question can be controlled, and the suppression of the conveying insects, so absolutely vital with certain of these diseases and so important in the others, can be brought about.

MOSQUITOES.

Aside from the loss occasioned by these insects as carriers of specific diseases, their abundance brings about a great monetary loss in other ways.

Possibly the greatest of these losses is in the reduced value of real estate in mosquito-infested regions, since these insects render absolutely uninhabitable large areas of land available for suburban homes, for summer resorts, for manufacturing purposes, and for agricultural pursuits. The money loss becomes most apparent in the vicinity of large centers of population. The mosquito-breeding regions in the vicinity of New York City, for example, have prevented the growth of paying industries of various kinds and have hindered the proper development of large regions to an amount which it is difficult to estimate in dollars and cents, and which is almost inconceivable. The same may be said for other large cities near the seacoast, and even of those inland in low-lying regions. The development of the whole State of New Jersey has been held back by the mosquito plague.

Agricultural regions have suffered from this cause. In portions of the Northwestern States it has been necessary to cover work horses in the field with sheets during the day. In the Gulf region of Texas at times the market value of live stock is greatly reduced by the abundance of insects. In portions of southern New Jersey there are lands eminently adapted to the dairying industry, contiguous to the markets of New York, Philadelphia, and the large New Jersey cities. In these localities herds of cattle have been repeatedly established, but the attacks by swarms of mosquitoes have reduced the yield in milk to such an extent as to make the animals unprofitable and dairying has been abandoned for occupations which are normally less remunerative. The condition of thoroughbred race horses at the great racing centers of Sheepshead Bay, Long Island, was so impaired by the attacks of mosquitoes as to induce those interested to spend many thousands of dollars a few years ago in an effort to abate the pest.

All over the United States, for these insects and for the house fly as well, it has become necessary, at great expense, to screen habitations. The cost of screening alone must surely exceed $10,000,000 per annum.

MALARIA.

The West Coast of Africa, portions of India, and many other tropical regions have always, at least down to the present period, been practically uninhabitable by civilized man owing to the presence of pernicious malaria. The industrial and agricultural development of Italy has been hindered to an incalculable degree by the prevalence of malaria in the southern half of the Italian peninsula, as well as in the velley of the Po and elsewhere. The introduction and spread of this disease in Greece is stated by Ronald Ross (and with strong reasons) to have been largely responsible for the progressive physical degeneration of one of the strongest races of the earth.

In the United States malaria, if not endemic, was early introduced. The probabilities are that it was endemic, and it is believed that the cause of failure of the early colonies in Virginia was due to this disease. It is certain that malaria retarded in a marked degree the advance of civilization over the North American Continent, and particularly was this the case in the march of the pioneers throughout the Middle West and throughout the Gulf States to the land west to and beyond the Mississippi. In many large regions once malarious the disease has lessened greatly in frequency and virulence owing to the reclamation of swamp areas and the lessening of the number of the possible breeding places of the malarial mosquitoes, but it is still enormously prevalent, particularly in the Southern States. There are many regions in the North where malaria is unknown, but in some of these localities *Anopheles* mosquitoes breed, and the absence of malaria means simply that malarial patients have not entered the regions at such time of the year as might produce a spread of the malady. It has happened again and again that in communities where malaria was previously unknown it has suddenly made its appearance and spread in a startling manner. These cases are sometimes to be explained, as happened in Brookline, Mass., by the introduction of Italian laborers, some of whom were malarious, to work upon the reservoir, or, as happened at a fashionable summer resort near New York City, by the appearance of a coachman who had had malaria elsewhere and suffered relapse at that place. In such ways, with a rapidly increasing population, malaria is still rapidly spreading in this country.

To attempt an estimate of the economic loss from the prevalence of malaria in the United States is a most difficult task. Prof. Irving Fisher, of Yale University, in one of his papers before the recent International Tuberculosis Congress, declared that tuberculosis costs the people of the United States more than $1,000,000,000 per year. In this estimate Professor Fisher considered the death rate for consumption, the loss of the earning capacity of the patients, the period of invalidism, and the amount of money expended in the care of the sick, together with other factors. In making these estimates he had a much more definite basis than can be gained for malaria. The death rate from malaria is comparatively small, and is apparently decreasing. Exact figures for the whole country are not available. From a table comprising 22 cities it appears that two-thirds of the deaths from malaria occur in the South, one-third only in the North. The death rates, by States, are available only for the following registration States: California, Colorado, Connecticut, District of Columbia, Indiana, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New York, New Jersey, Pennsylvania, Rhode Island, South Dakota, and Vermont, all of which are Northern States. For these States the census reports from 1900 to 1907, inclusive, give the following death rates:

Year.	Number per 100,000 population.	Deaths.
1900	7.9	2,434
1901	6.3	1,791
1902	5.4	1,738
1903	4.3	1,410
1904	4.2	1,391
1905	3.9	1,321
1906	3.5	1,415
1907	2.8	1,166
		12,666

Estimating from the preceding table the average annual death rate at 4.8 per 100,000 population, and considering that the registration area includes only 16 of the Northern States (assuming fairly, however, that the death rate in the other Northern States is the same), it seems reasonably safe to conclude that the death rate from malaria for the whole United States must surely amount to 15 per 100,000. It is probably greater than this, since the statistics from the South are city statistics, and malaria is really a country disease. This would give an annual loss by death from malaria of nearly 12,000 and a total number of deaths for the eight-year period (1900–1907) of approximately 96,000.

But with malaria, perhaps as with no other disease, does the death rate fail to indicate the real loss from the economic point of view. A man may suffer from malaria throughout the greater part of his life, and his productive capacity may be reduced by from 50 to 75 per cent, and yet ultimately he may die from some entirely different cause. In fact the predisposition to death from other causes brought about by malaria is so marked that if in the collection of vital statistics it were possible to ascribe the real influence upon mortality that malaria possesses, this disease would have a very high rank in mortality tables. Writing of tropical countries, Sir Patrick Manson states that malaria causes more deaths and more predisposition to death by inducing cachectic states disposing to other affections than all the other parasites affecting mankind together. Moreover, it has been shown that the average life of the worker in malarious places is shorter and the infant mortality higher than in healthy places.

But aside from this vitally important aspect of the subject the effect of malaria in lessening or destroying the productive capacity of the individual is obviously of the utmost importance, and upon the population of a malarious region is enormous, even under modern conditions and in this country. It has been suggested that the depopulation of the thickly settled Roman Campagna was due to the sudden introduction of malaria by the mercenaries of Sylla and Marius. Celli, in 1900, states that owing to malaria about 5,000,000 acres of land in Italy remain not uncultivated, but certainly very imperfectly cultivated. Then, also, in further example, in quite recent years malaria entered and devastated the islands of Mauritius and Reunion, practically destroying for a time the productiveness of these rich colonies of Great Britain and France.

Creighton, in his article on Malaria in the Encyclopedia Britannica, states that this disease "has been estimated to produce one-half of the entire mortality of the human race; and inasmuch as it is the most frequent cause of sickness and death in those parts of the globe that are most densely populated, the estimate may be taken as at least rhetorically correct."[a]

Is it possible to make any close estimate of the relation between the number of deaths from malaria and the number of cases of the same malady? No perfectly sound basis for such an estimate is apparent. In the English translation of Celli's work on "Malaria according to the new researches," published in London in 1900, it is stated that the mortality from malaria in Italy from 1887 to 1898 varied from 21,033 in the first-named year to 11,378 in the last named, and the mean mortality for the period is assumed to be about 15,000. In

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[a] See Darwinism and Malaria by R. G. Eccles, M. D., Medical Record, New York, January 16, 1909, pp. 85–93.

1896 a count of the patients in the hospitals in Rome was made, and the mortality rate of 7.75 per thousand of the actual patients was established. Calculating, then, on this basis and at this rate the number of cases per year for Italy was placed at about 2,000,000. According to this estimate and with the average mortality for the United States of 12,000, as above indicated, the approximate number of cases for the United States would be about 1,550,000. It seems obvious, however, that Celli, in using the basis of hospital patients only, must have underestimated the number of cases for the kingdom, since of the people in the country suffering from malaria the proportion entering the hospital must be relatively small. Therefore the death rate from malaria of malarial patients in the hospital must be greater than the death rate from malaria of the people who suffer from this disease in the whole country.

In fact so great must this discrepancy necessarily be that it would not seem at all unlikely to the writer if the number of persons suffering from malaria in Italy were in reality nearer 3,000,000 than 2,000,000. The same argument will hold for the United States, and the more especially so since, as a rule, malaria in this country is of a lighter type than in Italy, in fact an estimate of 3,000,000 cases of malaria in the United States annually is probably by no means too high. It will not be an exaggeration to estimate that one-fourth of the productive capacity of an individual suffering with an average case of malaria is lost, and accepting this as a basis, and including the loss through death, the cost of medicines, the losses to enterprises in malarious regions through the difficulty of securing competent labor and other factors, it is safe to place the annual loss to the United States from malarial disease under present conditions at not less than $100,000,000 annually. Celli has shown that in Italy the great railway industries, for example, feel the effect of malaria greatly. According to accurate calculations one company alone, for 1,400 kilometers of railway and for 6,416 workmen in malarious zones, spends on account of malaria 1,050,000 francs a year. The same writer states that the army in Italy from 1877 to 1897 had more than 300,000 cases of malaria.

The loss to this country in the way of retardation of the development of certain regions owing to the presence of malaria is extremely great. Certain territory containing most fertile soil and capable of the highest agricultural productiveness is practically abandoned. With the introduction of proper drainage measures and antimosquito work of other character, millions of acres of untold capacity could be released from the scourge at a comparatively slight expenditure. These regions in the absence of malaria would have added millions upon millions to the wealth of the country. Drainage measures are now being initiated by the Government. Parties of engineers are being sent by the Interior Department to make preliminary drainage surveys in the most prominent of these potentially productive regions. The following statement concerning the effect of malaria on the progress of this work has been made to the writer by Dr. George Otis Smith, Director of the United States Geological Survey:

In one of the Southern States 11 topographic parties have been at work during the past field season. The full quota for these parties would be 55 men, but I believe that something over 100 men have been employed at different times during the season. While I have not exact figures before me, I feel warranted in the statement that at least 95 per cent of these employees have been sick for periods ranging from a few days up to two weeks in the hospital. Many of them have been able later to return to work, but at least 30 per cent had to leave the field permanently. By reason of this sickness the efficiency of the parties was reduced, at a very conservative estimate, by 25 per cent.

In my recent visit in this field I found 1 man sick in each of the parties I saw, and 1 man who had just returned from the hospital leaving the field for good. A similar state of things was reported from the other parties. I regard the sickness as practically all of a malarial nature, as extreme care was taken in all the camps to use nothing but boiled water, except in a few instances, where artesian water from great depths was available. In all the camps the tents have been screened, and in every case where the topographer has lived for any time "on the country" there has been infection. As illustrating the value of the precautions generally taken by our camp parties I might cite the fact that last year in West Virginia, with 30 men living in a camp, with typhoid fever prevalent in the neighborhood, no cases developed, while with 6 men living on the country, where the same care could not be taken regarding the water supply, 2 cases of typhoid developed.

In estimating the weight of Doctor Smith's statement it must be borne in mind that the men of his field parties are exceptionally intelligent and prepared to take all ordinary precautions.

Throughout the region in question malaria is practically universal. The railroads suffer, and at the stations throughout the territory it is practically impossible to keep operators steadily at work. This reduction in efficiency in the surveying parties and in the local railroad officials is, moreover, probably very considerably less than the reduction in the earning capacity of the entire population, which, however, is necessarily scanty.

In an excellent paper entitled "The relation of malaria to agricultural and other industries of the South," published in the Popular Science Monthly for April, 1903, Prof. Glenn W. Herrick, then of the College of Agriculture of Mississippi, after a consideration of the whole field, concludes that malaria is responsible for more sickness among the white population of the South than any other disease to which that section is now subject. The following forcible statement, referring to the States of Louisiana, Mississippi, Alabama, Georgia, and South Carolina, is in Professor Herrick's words:

We must now consider briefly what 635,000 or 1,000,000 cases of chills and fevers in one year mean. It is a self-evident truth that it means well for the physician; but for laboring men it means an immense loss of their time, together with the doctors' fees in many instances. If members of their families other than themselves be affected, it may also mean a loss of time, together with the doctors' fees. For the employer it means the loss of labor at a time perhaps when it would be of greatest value. If it does not mean the actual loss of labor to the employer, it will mean a loss in the efficiency of his labor. To the farmers it may mean the loss of their crops by want of cultivation. It will always mean the noncultivation or imperfect cultivation of thousands of acres of valuable land. It means a listless activity in the world's work that counts mightily against the wealth-producing power of the people. Finally it means from two to five million or more days of sickness with all its attendant distress, pain of body, and mental depression to some unfortunate individuals of those five States.

Referring to the Delta region in Mississippi, which lies along the Mississippi River in the western part of the State extending from the mouth of the Yazoo River north nearly to the Tennessee line, Herrick says that it is the second best farming land in the world, having only one rival, and that is the Valley of the Nile. Herrick says:

Still this land to-day, or at least much of it, can be bought at $10 to $20 an acre. Thousands of acres in this region are still covered with the primeval forests, and bears and deer still roaming there offer splendid opportunities for the chase, as evidenced by the late visit of our ex-Chief Executive to those regions for the purpose of hunting. Why is not this land thickly settled? And why is it not worth from $200 to $500 an acre? If it produces from one to two or more bales of cotton on an acre, and it does, it ought to be worth the above-named figures. A bale of cotton to the acre can be produced for $13, leaving a net profit of $20 to $40 for each bale, or $40 to $80 or more for each acre of land cultivated. Moreover, this land has been doing that for years, and will do it for years to come, without the addition of one dollar's worth of fertilizer. Land that will produce a net profit of $40 to $80 an acre is a splendid investment at $100, $200, or even $300 an acre. Yet this land does not sell in the market for anything like so much, because the demand is not sufficient, for white people positively object to living in the Delta on account of malarial chills and fevers. A man said to me not long ago that he would go to the Delta that day if he were sure that his own life or the lives of the members of his family would not be shortened thereby. There are thousands exactly like him, and the only reason that these thousands do not go there to buy lands and make homes is on account of chills and fevers. But there is a time coming, and that not far distant, when malaria in the Delta will not menace the would-be inhabitants. When that time comes it will be the richest and most populous region in the United States.

Malaria is a preventable disease. It is possible for the human species to live, thrive, and produce in malarious regions, but at a very considerable inconvenience and expense. The Italian investigators, and especially Celli and his staff, have shown that by screening the huts of the peasants on the Roman Campagna and by furnishing field laborers with veils and gloves when exposed to the night air it is possible even in that famous hotbed of malaria to conduct farming operations with a minimum of trouble from the disease. Moreover, Koch and his assistants in German East Africa have shown that it is possible, by stamping out the disease among human beings by the free use of medicine, to reach a point where there is small opportunity for malarial mosquitoes to become infected. Moreover, the work of the parties sent out by the Liverpool School of Tropical Medicine and other English organizations to the west coast of Africa has shown that by proper treatment of malarial-mosquito breeding pools the pernicious coast fever may be greatly reduced. Again, the work of Englishmen in the Malay Federated States has shown that large areas may be practically freed from malaria. The most thorough and the most satisfactory of all measures consists in abolishing the breeding places of malarial mosquitoes. In regions like the Delta of Mississippi this involves extensive and systematic drainage, but in very many localities where the breeding places of the *Anopheles* mosquitoes can be easily eradicated, where they are readily located and are so circumscribed as to admit of easy treatment, it is possible to rid the section from malaria at a comparatively slight expense.

With a general popular appreciation of the industrial losses caused primarily by the malarial mosquito and, secondarily, by the nonmalarial carrying forms, as indicated in the opening paragraphs, it is inconceivable that the comparatively inexpensive measures necessary should not be undertaken by the General Government, by the state governments, and by the boards of health of communities, just as it is inconceivable that the individual should suffer from malaria and from the attacks of other mosquitoes when he has individual preventives and remedies at hand. Large-scale drainage measures by the General Government involving large sections of valuable territory have been planned and are practically under way; certain States, notably New Jersey and New York, are beginning to work; communities all over the country through boards of health are also beginning to take notice, while popular education regarding the danger from mosquitoes and in regard to remedial measures is rapidly spreading. But all of this interest should be intensified, and the importance of the work should be displayed in the most emphatic manner, and relief from malarial and other mosquito conditions should be brought about as speedily as possible.

A few excellent examples of antimalarial work may be instanced. The latest reports on the measures taken to abolish malaria from Klang and Port Swettenham in Selangor, Federated Malay States, indicate the most admirable results. These measures were undertaken first in 1901 and 1902 and have been reported upon from time to time in the Journal of Tropical Medicine. The expenditure undertaken by the Government with a view to improving the health of the inhabitants of these towns has been fully justified by the results, which promise to be of permanent value. The total expenditure for the town of Klang, down to the end of 1905, was £3,100, and the annual permanent expenditure is about £60 for clearing earth drains and £210 for town gardeners. For Port Swettenham the total expenditure to the end of 1905 was £7,000, and the annual cost of keeping up the drains, etc., is approximately £40 for clearing earth drains and £100 for town gardeners.

The careful tabulation of cases and deaths and of the results of the examination of blood of children in especially drained areas indicates the following conclusions: (1) Measures taken systematically to destroy breeding places of mosquitoes in these towns, the inhabitants of which suffered terribly from malaria, were followed almost immediately by a general improvement in health and decrease in death rate. (2) That this was due directly to the work carried out and not to a general dying out of malaria in the district is clearly shown by figures, pointing out that while malaria has practically ceased to exist in the areas treated, it has actually increased to a considerable extent in other parts of the district where antimalarial measures have not been undertaken.

The statistics for 1905 are even more favorable than those for 1902, which give a very strong evidence in favor of the permanent nature of the improvement carried out. In fact, it seems that malaria has been permanently stamped out at Klang and Port Swettenham by work undertaken in 1901, and this experience in the Malay States should be of value to those responsible for the health of communities similarly situated in many other parts of the world.

Another striking example of excellent work of this kind is found in the recently published report on the suppression of malaria in Ismaïlia, issued under the auspices of the Compagnie Universelle du Canal Maritime de Suez. Ismaïlia is now a town of 8,000 inhabitants. It was founded by De Lesseps in April, 1862, on the borders of Lake Timsah, which the Suez Canal crosses at middistance between the Red Sea and the Mediterranean. Malarial fever made its appearance in very severe form in September, 1877, although the city had up to that time been very healthful, and increased so that since 1886 almost all of the inhabitants have suffered from the fever. In 1901 an attempt to control the disease was made on the mosquito basis, and this attempt rapidly and completely succeeded, and after two years of work all traces of malaria disappeared from the city. The work was directed not only against *Anopheles* mosquitoes, but against other *Culicids*, and comprised the drainage of a large swamp and the other usual measures. The initial expense amounted to 50,000 francs, and the usual annual expenses since have amounted to about 18,300 francs.

The results may be summarized about as follows: Since the beginning of 1903 the ordinary mosquitoes have disappeared from Ismaïlia. Since the autumn of 1903 not a single larva of *Anopheles* has been found in the protected zone, which extends to the west for a distance of 1,000 meters from the first houses in the Arabian quarter, and to the east for a distance of 1,800 meters from the first houses in the European quarter. After 1902 malarial fever obviously began to decrease, and since 1903 not a single new case of malaria has been found in Ismaïlia.

A very efficient piece of antimalarial work was accomplished in Habana during the American occupation of 1901 and 1902, incidental in a way to the work against yellow fever. An *Anopheles* brigade of workmen was organized under the sanitary officer, Doctor Gorgas, for work along the small streams, irrigated gardens, and similar places in the suburbs, and numbered from 50 to 300 men. No extensive draining, such as would require engineering skill, was attempted, and the natural streams and gutters were simply cleared of obstructions and grass, while superficial ditches were made through the irrigated meadows. Among the suburban truck gardens *Anopheles* bred everywhere, in little puddles of water, cow tracks, horse tracks, and similar depressions in grassy ground. Little or no oil was used by the *Anopheles* brigade, since it was found in practice a simple matter to drain these places. At the end of the year it was very difficult to find water containing mosquito larvæ anywhere in the suburbs, and the effect upon malarial statistics was striking. In 1900, the year before the beginning of the mosquito work, there were 325 deaths from malaria; in 1901, the first year of the mosquito work, 171 deaths; in 1902, the second year of mosquito work, 77 deaths. Since 1902 there has been a gradual though slower decrease, as follows: 1903, 51; 1904, 44; 1905, 32; 1906, 26; 1907, 23. These results, although less striking than those from Ismaïlia, involved a smaller expense in money and show surely an annual saving of 300 lives, and undoubtedly a corresponding decrease in the number of malarial cases, which may be estimated upon our earlier basis at something less than 40,000.

YELLOW FEVER.

Yellow fever has prevailed endemically throughout the West Indies and in certain regions on the Spanish Main virtually since the discovery of America. The Barbados, Jamaica, and Cuba suffered epidemics before the middle of the seventeenth century. There were outbreaks in Philadelphia, Charleston, and Boston as early as 1692, and for a hundred years there were occasional outbreaks, culminating in the great Philadelphia epidemic of 1793. Northern cities were able by rigid quarantine measures to prevent great epidemics after the early part of the nineteenth century, but from the West Indies the disease was occasionally introduced and prevailed from time to time epidemically in the Southern States. In 1853 it raged throughout this region, New Orleans alone having a mortality of 8,000. The last widespread epidemic occurred in 1878, chiefly in Louisiana, Alabama, and Mississippi, but spreading up the Mississippi Valley as far as Cairo, Ill., attacking with virulence the city of Memphis, Tenn. In this year there were 125,000 cases and 12,000 deaths. In 1882 there were 192 deaths at Pensacola; in 1887, 62 deaths in the Southern States; in 1893, 52 deaths; in 1897, 484; in 1898, 2,456 cases, with 117 deaths; in 1903, 139 deaths were recorded, mostly at Laredo, Tex.; and in 1905 there was a serious outbreak at New Orleans and in neighboring towns, including one locality in Mississippi, in which 911 deaths were recorded for the whole country.

The actual loss of life from yellow fever during all these years, when compared to the loss from other diseases, has been comparatively slight, but the death rate is perhaps the most insignificant feature of the devastation which yellow-fever epidemics have produced, and the disease itself has been but a small part of the affliction which it has brought to the Southern States. The disease once discovered in epidemic form, the whole country has become alarmed; commerce in the affected region has come virtually to a standstill; cities have been practically deserted; people have died from exposure in camping out in the highlands; rigid quarantines have been established; innocent persons have been shot while trying to pass these quarantine lines; all industry for the time has ceased. The commerce of the South during the epidemic of 1878, for example, fell off 90 per cent, and the hardships of the population can not be estimated in monetary terms. With such industrial and commercial conditions existing from Texas to South Carolina, many industries at the North have suffered, and, in fact, the effect of a yellow-fever summer in the South has been felt not only all over the United States, but in many other portions of the world.

All these conditions, as bad as they have been, do not sum up the total loss to the national prosperity during past years. Cities like Galveston, New Orleans, Mobile, Memphis, Jacksonville, and Charleston, subject to occasional epidemics, as they have been in the past, have not prospered as they should. Their progress has been greatly impeded by this one cause, and thus the industrial development of the entire South has been greatly retarded.

Physicians had been theorizing about the cause of yellow fever from the time when they began to treat it. It was thought by many that it was carried in the air; by others that it was conveyed by the clothing, bedding, or other articles which had come in contact with a yellow-fever patient. There were one or two early suggestions of the agency of mosquitoes, but practically no attention was paid to them, and they have been resurrected and considered significant only since the beginning of the present century. With the discovery of the agency of micro-organisms in the causation of disease, a search soon began for some causative germ. Many micro-organisms were found in the course of the autopsies and many claims were put forth by investigators. All of these, however, were virtually set at rest by Sternberg in his "Report on the Etiology and Prevention of Yellow Fever," published in 1890, but a claim made by Sanarelli in June, 1897, for a bacillus which he called *Bacillus icteroides* received considerable credence, and in 1899 it was accepted in full by Wasden and Geddings, of the Marine-Hospital Service, who reported that they had found this bacillus in 13 or 14 cases of yellow fever in the city of Habana. There is no evidence, however, that this bacillus has anything to do with yellow fever. In 1881 Finlay, of Habana, proposed the theory that yellow fever whatever its cause may be is conveyed by means of *Culix* (now *Stegomyia*) *fasciatus* (now *calopus*). Subsequently he published several important papers in which his views were modified from time to time, and in the course of which he mentioned experiments with 100 individuals, producing 3 cases of mild fever. None of the cases, however, was under his full control, and the possibility of other methods of gaining the disease was not excluded. Therefore his theory, while it was received with interest, was not considered to be proved.

In 1890 came the beginning of the true demonstration. An army board was appointed by Surgeon-General Sternberg for the purpose of investigating the acute infectious diseases prevailing in the island of Cuba. The result achieved by this board, consisting of Reed, Carroll, Lazear, and Agramonte, was a demonstration that yellow fever is carried by *Stegomyia calopus*, and their ultimate demonstration was so perfect as to silence practically all expert opposition. The Third International Sanitary Convention of the American Republics unanimously accepted the conclusion that yellow fever is carried by this mosquito and that the *Stegomyia* constitutes the only known means by which the disease is spread. To-day, after abundant additional demonstration, the original contention of Reed, Carroll, and Agramonte (Lazear having died in the course of the experiments) is a part of the accepted knowledge of the medical world. The importance of the discovery can not be overestimated, and its first demonstration was followed by antimosquito measures in the city of Habana, undertaken, under the direction of Gorgas, with startling results.

Yellow fever had been endemic in Habana for more than one hundred and fifty years, and Habana was the principal source of infection for the rest of Cuba. Other towns in the island could have rid themselves of the disease if they had not been constantly reinfected from Habana. By ordinary sanitary measures of cleanliness, improved drainage, and similar means the death rate of the city was improved from an average of 40 per thousand under Spanish rule to 22 per thousand in 1900, but these measures had no effect upon yellow fever, this disease increasing as the nonimmune population following the Spanish war increased.

Stegomyia calopus was established as the carrier of the fever early in 1901, and then antimosquito measures were immediately begun. Against adult mosquitoes no general measures were attempted, although screening and fumigation were carried out in quarters occupied by yellow-fever patients. It was found that the *Stegomyia* bred principally in the rain-water collections in the city itself. The city was divided into about 30 districts, and to each district an inspector and two laborers were assigned—each district containing about a thousand houses. An order was issued by the mayor of Habana requiring all collections of water to be so covered that mosquitoes could not have access, a fine being imposed in cases where the order was not obeyed. The health department covered the rain-water barrels of poor families at public expense. All cesspools were treated with petroleum. All receptacles containing fresh water which did not comply with the law were emptied and on the second offense destroyed. The result of this work thoroughly done was to wipe out yellow fever in Habana, and for four years there was not a case in Habana or in Cuba.

In what is termed the "New Orleans epidemic of 1905," a striking illustration of the value of this recently acquired mosquito-transmission knowledge is seen. The presence of yellow fever in the city was first recognized about the 1st of July, but it was the 12th of August before the Public Health and Marine-Hospital Service was put in complete control of the situation. By that time the increase in new cases and deaths rendered it practically certain that the disease was as widespread as during the terrible epidemic of 1878. There had been up to that date 142 deaths from a total of 913 cases, as against 152 deaths from a total of 519 cases in 1878. The Public Health and Marine-Hospital Service, under Doctor White, took hold of the situation with energy, basing its measures almost entirely upon a warfare against *Stegomyia calopus*. The disease began almost immediately to abate, and the result at the close of the season indicated 460 deaths, as against 4,046 in 1878, a virtual saving of over 3,500 lives. The following table of deaths from yellow fever in New Orleans from 1847 to 1905 points out most strikingly the value of this antimosquito work:

Comparative table of deaths from yellow fever in New Orleans.

Months.	1847.	1848.	1853.	1854.	1855.	1858.	1867.	1878.	1905.
May	....	....	2	....	....	....	....	....	....
June	....	4	31	2	5	2	3	....	....
July	74	33	1,521	29	382	132	11	26	35
August	965	200	5,133	532	1,286	1,140	255	1,025	236
September	1,100	467	982	1,234	874	2,204	1,637	1,780	107
October	198	126	147	490	97	1,137	1,072	1,065	59
November	12	20	28	131	19	224	103	147	23
December	10	....	4	7	7	15	26	3	....
Months unknown	445	22	....	....	....	....	....	....	....
Total	2,804	872	7,848	2,425	2,670	4,854	3,107	4,046	460

The epidemics of 1848, 1854, and 1855 are least comparable with that of 1905, because they immediately succeed severe epidemics to which were due very many immunes.

Population of New Orleans by United States Census: 130,565 in 1850; 168,675 in 1860; 191,418 in 1870; 216,090 in 1880; and 287,104 in 1900.

WORK ON THE ISTHMUS OF PANAMA.

The United States Government has very properly used the services of Colonel Gorgas, who was in charge of the eminently successful work at Habana, by appointing him chief sanitary officer of the Canal Zone during the digging of the canal. In 1904 active work was begun, and Colonel Gorgas was fortunate in having the services of Mr. Le Prince, who had been chief of his mosquito brigades in Habana, and therefore was perfectly familiar with antimosquito methods. In Panama, the population had depended principally upon rain water for domestic purposes, so that every house had cisterns, water barrels, and such receptacles for catching and storing rain water. The city was divided into small districts with an inspector in charge of each district. This inspector was required to cover his territory at least twice a week and to make a report upon each building with regard to its condition as to breeding places of mosquitoes. All the cisterns, water barrels, and other water receptacles in Panama were covered as in Habana, and in the water barrels spigots were inserted so that the covers would not have to be taken off. Upon first inspection, in March, 4,000 breeding places were reported. At the end of October less than 400 containing larvæ were recorded. This gives one a fair idea of the consequent rapid decrease in the number of mosquitoes in the city. These operations were directed primarily against the yellow-fever mosquito, and incidentally against the other common species that inhabit rain-water barrels. Against the *Anopheles* in the suburbs the same kind of work was done as in Habana, with exceptionally good results.

The same operations were carried on in the villages between Panama and Colon. There are some twenty of these, running from 500 to 3,000 inhabitants each. Not a single instance of failure has occurred in the disinfection of these small towns, and the result of the work has been the apparent elimination of yellow fever and the very great reduction of malarial fever. The remarkable character of these results can only be judged accurately by comparative methods. It is well known that during the French occupation there was an enormous mortality among European employees, and this was a vital factor in the failure of the work. Exact losses can not be estimated, since the work was done under 17 different contractors. These contractors were charged $1 a day for every sick man to be taken care of in the hospital of the company. Therefore it often happened that when a man became sick his employer discharged him so that he would not have to bear the expense of hospital charges. There was no police patrol of the territory. A great many of these men were found to have died along the roadside while endeavoring to find their way to the city of Panama. Colonel Gorgas has stated that the English consul, who was at the Isthmus during the period of the French construction, is inclined to think that more deaths of employees occurred out of the hospital than in it. The old superintendent of the French hospital states that one day 3 of the medical staff died from yellow fever, and in the same month 9 of the medical staff. Thirty-six Roman Catholic sisters were brought over as nurses, of whom 24 died of yellow fever. On one vessel 18 young French engineers came over, and within a month all but 1 died.

Now that the relation of the mosquito to yellow fever is well understood, it was found during the first two years under Colonel Gorgas that although there were constantly one or more yellow-fever cases in the hospital, and although the nurses and physicians were all nonimmunes, not a single case of yellow fever was contracted in that way. The nurses never seemed to consider that they were running any risk in attending yellow-fever cases night and day in screened wards, and the wives and families of officers connected with the hospital lived about the grounds, knowing that yellow fever was constantly being brought into the grounds and treated in near-by buildings. Americans, sick from any cause, had no fear of being treated in beds immediately adjoining those of yellow-fever patients. Colonel Gorgas and Doctor Carter lived in the old ward used by the French for their officers, and Colonel Gorgas thinks it safe to say that more men had died from yellow fever in that building under the French régime than in any other building of the same capacity at present standing. He and Doctor Carter had their wives and children with them, which would formerly have been considered the height of recklessness; but they looked upon themselves, under the now recognized precautions, almost as safe as they would have been in Philadelphia or Boston.

No figures of actual cost of the antimosquito work, either in Habana or in the Panama Canal Zone, are accessible to the writer, but it is safe to say that it was not exorbitant, and that it was not beyond the means of any well-to-do community in tropical regions.

THE TYPHOID FLY, COMMONLY KNOWN AS THE "HOUSE FLY."

The name "typhoid fly" is here proposed as a substitute for the name "house fly," now in general use. People have altogether too long considered the house fly as a harmless creature, or, at the most, simply a nuisance. While scientific researches have shown that it is a most dangerous insect from the standpoint of disease, and while popular opinion is rapidly being educated to the same point, the retention of the name "house fly" is considered inadvisable as perpetuating in some degree the old ideas. Strictly speaking, the term "typhoid fly" is open to some objection as conveying the erroneous idea that this fly is solely responsible for the spread of typhoid; but considering that the insect is dangerous from every point of view, and that it is an important element in the spread of typhoid, it seems advisable to give it a name which is almost wholly justified and which conveys in itself the idea of serious disease. Another repulsive name that might be given to it is the "manure fly;" but recent researches have shown that it is not confined to manure as a breeding place, although perhaps the great majority of these flies are so propagated. For the end in view "typhoid fly" is considered the best name.

The true connection and the true scientific evidence regarding the rôle of the so-called "house fly" with typhoid fever has only recently been worked out. Celli, in 1888, fed flies with pure cultures of the *Bacillus typhi-abdominalis*, and examined their contents and dejections microscopically and culturally. Inoculations of animals were also made, proving that the bacilli which passed through flies were virulent. Dr. George M. Kober, who is familiar with Celli's researches, in his report on the prevalence of typhoid fever in the District of Columbia, published in 1895, called especial attention to the danger of the contamination of food supplies by flies coming from the excreta of typhoid patients. The prevalence of typhoid fever in the concentration camps of the United States Army in the summer of 1898 brought about the appointment of an army typhoid commission, consisting of Dr. Walter Reed, U. S. Army; Dr. Victor M. Vaughan, U. S. Volunteers; and Dr. E. O. Shakespeare, U. S. Volunteers. A paper read by Doctor Vaughan before the annual meeting of the American Medical Association at Atlantic City, N. J., June 6, 1900, contained the following conclusions with regard to flies:

27. *Flies undoubtedly served as carriers of the infection.*—My reasons for believing that flies were active in the dissemination of typhoid may be stated as follows:

"*a.* Flies swarmed over infected fecal matter in the pits and then visited and fed upon the food prepared for the soldiers at the mess tents. In some instances where lime had recently been sprinkled over the contents of the pits, flies with their feet whitened with lime were seen walking over the food.

"*b.* Officers whose mess tents were protected by means of screens suffered proportionately less from typhoid fever than did those whose tents were not so protected.

"*c.* Typhoid fever gradually disappeared in the fall of 1898, with the approach of cold weather, and the consequent disabling of the fly.

"It is possible for the fly to carry the typhoid bacillus in two ways. In the first place, fecal matter containing the typhoid germ may adhere to the fly and be mechanically transported. In the second place, it is possible that the typhoid bacillus may be carried in the digestive organs of the fly and may be deposited with its excrement."

There were also many important conclusions which bear upon the fly question. For example, it was shown that every regiment in the United States service in 1898 developed typhoid fever, nearly all of them within eight weeks after assembling in camps. It not only appeared in every regiment in the service, but it became epidemic both in small encampments of not more than one regiment and in the larger ones consisting of one or more corps. All encampments located in the Northern, as well as in the Southern States, exhibited typhoid in epidemic form. The miasmatic theory of the origin of typhoid fever and the pythogenic theory [a] were not supported by the investigations of the commission, but the doctrine of the specific origin of fever was confirmed. The conclusion was reached that the fever is disseminated by the transference of the excretions of an infected individual to the alimentary canals of others, and that a man infected with typhoid fever may scatter the infection in every latrine or regiment before the disease is recognized in himself, while germs may be found in the excrement for a long time after the apparently complete recovery of the patient. Infected water was not an important factor in the spread of typhoid in the national encampments of 1898, but about one-fifth of the soldiers in the national encampments in the United States during that summer developed this disease, while more than 80 per cent of the total deaths were caused by typhoid.

In 1899 the writer began the study of the typhoid or house fly under both country and city conditions. He made a rather thorough investigation of the insect fauna of human excrement, and made a further investigation of the species of insects that are attracted to food supplies in houses. In a paper entitled "A contribution to the study of the insect fauna of human excrement (with especial reference to the spread of typhoid fever by flies)," published in the Proceedings of the Washington Academy of Sciences, Volume II, pages 541–604, December 28, 1900, he showed that 98.8 per cent of the whole number of insects captured in houses throughout the whole country under the conditions indicated above were *Musca domestica*, the typhoid or house fly. He showed further that this fly, while breeding most numerously in horse stables, is also attracted to human excrement and will breed in this substance. It was shown that in towns where the box privy was still in existence the house fly is attracted to the excrement, and, further, that it is so attracted in the

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[a] This theory is founded upon the belief that the colon germ may undergo a ripening process by means of which its virulence is so increased and altered that it may be converted into the typhoid bacillus, or at least may become the active agent in the causation of typhoid fever.

filthy regions of a city where sanitary supervision is lax and where in low alleys and corners and in vacant lots excrement is deposited. He stated that he had seen excrement which had been deposited overnight in an alleyway in south Washington swarming with flies under the bright sunlight of a June morning (temperature 92° F.), and that within 30 feet of these deposits were the open windows and doors of the kitchens of two houses kept by poor people, these two houses being only elements in a long row. The following paragraph is quoted from the paper just cited:

> Now, when we consider the prevalence of typhoid fever and that virulent typhoid bacilli may occur in the excrement of an individual for some time before the disease is recognized in him and that the same virulent germs may be found in the excrement for a long time after the apparent recovery of a patient, the wonder is not that typhoid is so prevalent but that it does not prevail to a much greater extent. Box privies should be abolished in every community. The depositing of excrement in the open within town or city limits should be considered a punishable misdemeanor in communities which have not already such regulations, and it should be enforced more rigorously in towns in which it is already a rule. Such offenses are generally committed after dark and it is often difficult or even impossible to trace the offender; therefore the regulation should be carried even further and require the first responsible person who notices the deposit to immediately inform the police so that it may be removed or covered up. Dead animals are so reported, but human excrement is much more dangerous. Boards of health in all communities should look after the proper treatment or disposal of horse manure, primarily in order to reduce the number of house flies to a minimum, and all regulations regarding the disposal of garbage and foul matter should be made more stringent and should be more stringently enforced.

In the opening sentence of the paragraph just quoted attention was called to the activity of bacilli in excreta passed by individuals after apparent recovery from typhoid. Since the paper in question was published more especial attention has been drawn by medical men to this point, and it has been shown that individuals who are chronic spreaders of the typhoid germs are much more abundant than was formerly supposed. Dr. George A. Soper recently discovered a striking case of this kind in the person of a cook employed successively by several families in the vicinity of New York City, with the result that several cases of typhoid occurred in each of these families. In a paper by Doctor Davies and Professor Walker, read before the Royal Sanitary Institute of London during the present season, the history was given of four personal carriers of typhoid who had communicated the disease to a number of people. These four carriers were detected in one city within a few months, and from this fact it can be argued with justice that such cases are comparatively numerous. This being the case, the danger of unguarded miscellaneous human excreta deposited in city suburbs, in vacant lots, in low alleyways, intensifies to a very marked degree the danger of food contamination with typhoid bacilli by means of the typhoid or house fly. It is well known, too, that the urine of persons who have suffered from typhoid fever often contains typhoid bacilli for several weeks after the patients have recovered; consequently, this also is a source of danger.

The importance of the typhoid fly as a carrier of the disease in army camps, as shown in the Spanish war and in the Boer war and in the camps of great armies of laborers engaged in gigantic enterprises like the digging of the Panama Canal, the evidence that has just been stated indicates that even under city conditions the influence of this fly in the spread of this disease has been greatly underestimated. It is not claimed that under city conditions the house fly becomes by this argument a prime factor in the transfer of the disease, but it must obviously take a much higher relative rank among typhoid conveyers than it has hitherto assumed. Perhaps even under city conditions it must assume third rank—next to water and milk.

It is not alone as a carrier of typhoid that this fly is to be feared. In the same way it may carry nearly all intestinal diseases. It is a prime agent in the spreading of summer dysentery, and in this way is unquestionably responsible for the death of many children in summer. One of the earliest accurate scientific studies of the agency of insects in the transfer of human disease was in regard to flies as spreaders of cholera. The belief in this agency long preceded its actual proof. Dr. G. E. Nicholas, in the London Lancet,[a] is quoted by Nuttall as writing, in 1849, when cholera prevailed at Malta:

> My first impression of the possibility of the transfer of the disease by flies was derived from the observation of the manner in which these voracious creatures, present in great numbers and having equal access to the dejections and food of patients, gorged themselves indiscriminately and then disgorged themselves on the food and drinking utensils. In 1850 the *Superb*, in common with the rest of the Mediterranean squadron, was at sea nearly six month. During the greater part of the time she had cholera on board. On putting to sea, the flies were in great force; but after a time they gradually disappeared and the epidemic slowly subsided. On going into Malta Harbor, but without communicating with the shore, the flies returned in greater force and the cholera also with increased violence. After more cruising at sea the flies disappeared gradually with the subsidence of the disease.

Accurate scientific bacteriological observations by Tizzoni and Cattani in 1886 showed definitely active cholera organisms in the dejecta of flies caught in the cholera wards in Bologna. These observations were subsequently verified and extended by Simonds, Offelmann, Macrae, and others.

With tropical dysentery and other enteric diseases practically the same conditions exist. In a report by Daniel D. Jackson to the committee on pollution of the Merchants' Association in New York, published in December, 1907, the results of numerous observations upon the relation of flies to intestinal disease are published, and the relation of deaths from intestinal diseases in New York City to the activity and prevalence of the common house fly is shown not only by repeated observations, but also by an interesting plotting of the curve of abundance of flies in comparison with the plotted curve of abundance of deaths from intestinal diseases, indicating that the greatest numbers of flies occurred in the weeks ending July 27 and August 3; that the deaths from intestinal diseases rose above the normal at the same time at which flies became prevalent, culminated at the same high point, and fell off with slight lag at the time of the gradual falling off of the prevalence of the insects.

Similar studies have been carried on during the summer of 1908 in the city of Washington, and the curve of typhoid fly abundance for the whole city as well as that for a district comprising eight city squares, in which intensive studies have been made both of flies and

[a] Volume II, 1873, p. 724.

of disease, will be plotted at the close of the season. At the time of writing this work has not been completed.

The typhoid fly also possesses importance as a disseminator of the bacilli of tuberculosis. In a paper by Dr. Frederick T. Lord, of Boston,[a] the following conclusions are reached:

1. Flies may ingest tubercular sputum and excrete tubercle bacilli, the virulence of which may last for at least fifteen days.

2. The danger of human infection from tubercular flyspecks is by the ingestion of the specks on food. Spontaneous liberation of tubercle bacilli from flyspecks is unlikely. If mechanically disturbed, infection of the surrounding air may occur.

As a corollary to these conclusions it is suggested that—

3. Tubercular material (sputum, pus from discharging sinuses, fecal matter from patients with intestinal tuberculosis, etc.) should be carefully protected from flies lest they act as disseminators of the tubercle bacilli.

4. During the fly season greater attention should be paid to the screening of rooms and hospital wards containing patients with tuberculosis and laboratories where tubercular material is examined.

5. As these precautions would not eliminate fly infection by patients at large, foodstuffs should be protected from flies which may already have ingested tubercular material.

From all these facts it appears that the most important part played by the typhoid fly or house fly in the human economy is to carry bacteria from one place to another. The following table and comments are taken from Bulletin No. 51 (April, 1908) of the Storrs Agricultural Experiment Station, Storrs, Conn., entitled "Sources of Bacteria in Milk," by W. M. Esten and C. J. Mason.

Sources of bacteria from flies.

Date.	Source.	Total number.	Total acid bacteria.	Rapid liquefying bacteria.	Slow liquefying bacteria.	Bacterium lactis acidi (Group A, Class 1).	Coli-aerogenes (Group A, Class 2).
1907. July 27	(a) 1 fly, bacteriological laboratory...	3,150	250	600	100	....	....
July 27	(b) 1 fly, bacteriological laboratory...	550	100	0	0	....	....
Aug. 6	(c) 19 cow stable flies	7,980,000	220,000	0	20,000	....	....
	Average per fly.	420,000	11,600	0	1,000	....	....
Aug. 14	(d) 94 swill barrel flies.............	155,000,000	8,950,000	0	0	4,320,000	4,630,000
	Average per fly.	1,660,000	95,300	0	0	46,000	49,300
Aug. 14	(e) 144 pig pen flies.	133,000,000	2,110,000	100,000	265,000	933,000	1,176,000
	Average per fly.	923,000	18,700	700	1,150	6,500	12,200
Sept. 4	(f) 18 swill barrel flies.............	118,800,000	40,480,000	0	14,500,000	10,480,000	30,000,000
	Average per fly.	6,600,000	2,182,000	0	804,000	582,000	1,600,000
Sept. 21	(g) 30 dwelling house flies........	1,425,000	125,000	0	12,500	....	....
	Average per fly.	47,580	4,167	0	417	....	....
Sept. 21	(h) 26 dwelling house flies........	22,880,000	22,596,000	120,000	34,000	....	....
	Average per fly.	880,000	869,000	4,600	1,300	....	....

[a] Reprinted from the Boston Medical and Surgical Journal for Dec. 15, 1904, pp. 651–654.

Sources of bacteria from flies—Continued.

Date.	Source.	Total number.	Total acid bacteria.	Rapid liquefying bacteria.	Slow liquefying bacteria.	Bacterium lactis acidi (Group A, Class 1).	Coli-aerogenes (Group A, Class 2).
1907. Sept. 27	(*i*) 110 dwelling house flies........	35,500,000	13,670,000	8,840,000	125,000	....	....
	Average per fly.	322,700	124,200	80,300	1,100	....	....
Aug. 20	(*j*) 1 large blue bottle blow fly.......	308,700	(*a*)	....	....	....	....
	Total average of 414 flies...	1,222,570	367,300	7,830	73,500	....	....
	Average percentage of 414 flies......	....	30	6	6	....	....
	Average per fly of 256 flies, experiments (*d*), (*e*), and (*f*)...........	3,061,000	765,000	230	268,700	211,500	553,800
	Average per cent of 256 flies, experiments (*d*), (*e*), and (*f*)..	....	25	....	8	7	18

[a] 2,200 mold spores.

From the above table the bacterial population of 414 flies is pretty well represented, the domestic fly passing from a disgusting nuisance and troublesome pest to a reputation of being a dangerous enemy to human health. A species of mosquito has been demonstrated to be the cause of the spread of malaria. Another kind of mosquito is the cause of yellow fever, and now the house fly is considered an agency in the distribution of typhoid fever, summer complaint, cholera infantum, etc.

The numbers of bacteria on a single fly may range all the way from 550 to 6,600,000. Early in the fly season the numbers of bacteria on flies are comparatively small, while later the numbers are comparatively very large. The place where flies live also determines largely the numbers that they carry. The average for the 414 flies was about 1,250,000 bacteria on each. It hardly seems possible for so small a bit of life to carry so large a number of organisms. The method of the experiment was to catch the flies from the several sources by means of a sterile fly net, introduce them into a sterile bottle, and pour into the bottle a known quantity of sterilized water, then shake the bottle to wash the bacteria from their bodies, to simulate the number of organisms that would come from a fly in falling into a lot of milk. In experiments (*d*), (*e*), and (*f*) the bacteria were analyzed into four groups. The objectionable class, coli-aerogenes type, was 2½ times as abundant as the favorable acid type. If these flies stayed in the pigpen vicinity there would be less objection to the flies and the kinds of organisms they carry, but the fly is a migratory insect, and it visits everything "under the sun." It is almost impossible to keep it out of our kitchens, dining rooms, cow stables, and milk rooms. The only remedy for this rather serious condition of things is to remove the pigpen as far as possible from the dairy and dwelling house. Extreme care should be taken in keeping flies out of the cow stable, milk rooms, and dwellings. Flies walking over our food are the cause of one of the worst contaminations that could occur from the standpoint of cleanliness and the danger of distributing disease germs.

The danger of the typhoid or house fly in the carriage of disease has thus been abundantly demonstrated. Further than this, it is an intolerable nuisance. With mosquitoes, it necessitates an annual outlay for window and door screens in the United States of not less than $10,000,000. As a carrier of disease it causes a loss of many millions of dollars annually. Dr. G. M. Kober, in a paper prepared for the governors' conference on the conservation of natural resources, held at the White House in May, 1908, entitled "The conservation of life and health by improved water supply," presented figures showing that the decrease in the vital assets of the country through typhoid fever in a single year is more than $350,000,000. The house fly, as an important agent in the spread of this disease, is responsible for a very considerable portion of this decrease in vital assets. As an agency in the spread of other intestinal diseases, this sum must be greatly increased, and yet the fly is allowed to breed unrestricted all over the United States; it is allowed to enter freely the houses of the great majority of our people; it is allowed to spread bacteria freely over our food supplies in the markets and in the kitchens and dining rooms of private houses; and, to use the happy phraseology of Dr. Theobald Smith, "When we go into public restaurants in midsummer, we are compelled to fight for our food with the myriads of house flies which we find there, alert, persistent, and invincible."

Even if the typhoid or house fly were a creature difficult to destroy, the general failure on the part of communities to make any efforts whatever to reduce its numbers could properly be termed criminal neglect, but since, as will be shown, it is comparatively an easy matter to do away with the plague of flies, this neglect becomes an evidence of ignorance or of a carelessness in regard to disease-producing filth which to the informed mind constitutes a serious blot on civilized methods of life.

Strange as it may seem, an exhaustive study of the conditions which produce house flies in numbers has never been made. The life history of the insect in general was, down to 1873, mentioned in only three European works and few exact facts were given. In 1873 Dr. A. S. Packard, then of Salem, Mass., studied the transformations of the insect and gave descriptions of all stages, showing that the growth of a generation from the egg state to the adult occupies from ten to fourteen days.

In 1895 the writer traced the life history in question, indicating that 120 eggs are laid by a single female, and that in Washington in midsummer a generation is produced every ten days. Although numerous substances were experimented with, he was able to breed the fly only in horse manure. Later investigations indicated that the fly will breed in human excrement and in other fermenting vegetable and animal material, but that the vast majority of the flies that infest dwelling houses both in cities and on farms come from horse manure.

In 1907 careful investigations carried on in the city of Liverpool by Robert Newstead, lecturer in economic entomology and parasitology in the School of Tropical Medicine of the University of Liverpool, indicated that the chief breeding places of the house fly in that city should be classified under the following heads: (1) Middensteads (places where dung is stored) containing horse manure only; (2) middensteads containing spent hops; (3) ash pits containing fermenting materials.

He found that the dung heaps of stables containing horse manure only were the chief breeding places. Where horse and cow manures were mixed, the flies bred less numerously, and in barnyards where fowls were kept and allowed freedom relatively few house flies were found. Only one midden containing warm spent hops was inspected, and this was found to be as badly infested as any of the stable middens. A great deal of time was given to the inspection of ash pits, and it was found that wherever fermentation had taken place and artificial heat had been thus produced such places were infested with house fly larvæ and pupæ often to the same alarming extent as in stable manure. Such ash pits as these almost invariably contained large quantities of old bedding or straw and paper, paper mixed with human excreta, or old rags, manure from rabbit hutches, etc., or a mixture of all these. About 25 per cent of the ash pits examined were thus infested, and house flies were found breeding in smaller numbers in ash pits in which no heat had been engendered by fermentation. The house fly was also found breeding by Mr. Newstead in certain temporary breeding places, such as collections of fermenting vegetable refuse, accumulations of manure at wharves, and in bedding in poultry pens.

Still more recent investigations have been carried on during the year 1908 by Prof. S. A. Forbes, state entomologist of Illinois, who has reared it in large numbers from the contents of paunches of slaughtered cattle, from refuse hog hairs, from tallow vats, from carcasses of various animals, miscellaneous garbage, and so on.

All this means that if we allow the accumulation of filth we will have house flies, and if we do not allow it to accumulate we will have no house flies. With the careful collection of garbage in cans and the removal of the contents at more frequent intervals than ten days, with the proper regulation of abattoirs, and particularly with the proper regulations of stables in which horses are kept, the typhoid fly will become a rare species. It will not be necessary to treat horse manure with chloride of lime or with kerosene or with a solution of paris green or arsenate of lead, if stable men are required to place the manure daily in a proper covered receptacle and it is carried away once a week.

The orders of the health department of the District of Columbia, published May 3, 1906, if carried out, will be very effective. These orders may briefly be condensed as follows:

All stalls in which animals are kept shall have the surface of the ground covered with a water-tight floor. Every person occupying a building where domestic animals are kept shall maintain, in connection therewith, a bin or pit for the reception of manure, and pending the removal from the premises of the manure from the animal or animals, shall place such manure in said bin or pit. This bin shall be so constructed as to exclude rain water, and shall in all other respects be water-tight except as it may be connected with the public sewer. It shall be provided with a suitable cover and constructed so as to prevent the ingress or egress of flies. No person owning a stable shall keep any manure or permit any manure to be kept in or upon any portion of the premises other than the bin or pit described, nor shall he allow any such bin or pit to be overfilled or needlessly uncovered. Horse manure may be kept tightly rammed into well-covered barrels for the purpose of removal in such barrels. Every person keeping manure in any of the more densely populated parts of the District shall cause all such manure to be removed from the premises at least twice every week between June 1 and October 31, and at least once every week between November 1 and May 31 of the following year. No person shall remove or transport any manure over any public highway in any of the more densely populated parts of the District except in a tight vehicle which, if not inclosed, must be effectually covered with canvas so as to prevent the manure from being dropped. No person shall deposit manure removed from the bins or pits within any of the more densely populated parts of the District without a permit from the health officer. Any person violating any of these provisions shall, upon conviction thereof, be punished by a fine of not more than $40 for each offense.

In addition to this excellent ordinance, others have been issued from the health department of the District of Columbia which provide against the contamination of exposed food by flies and by dust. The ordinances are excellently worded so as to cover all possible cases. They provide for the registration of all stores, markets, cafes, lunch rooms, or of any other place where food or beverage is manufactured or prepared for sale, stored for sale, offered for sale, or sold, in order to facilitate inspection, and still more recent ordinances provide for the registration of stables. An excellent campaign was begun during the summer of 1908 against insanitary lunch rooms and restaurants. A number of cases were prosecuted, but conviction was found to be difficult.

For one reason or another, the chief reason being the lack of a sufficient force of inspectors under the control of the health officer, the ordinance in regard to stables has not been carried out with that perfection which the situation demands. In the summer of 1896 the health officer of the District, Dr. W. C. Woodward, designated a region in Washington bounded by Pennsylvania avenue, Sixth street, Fifteenth street, and the Potomac River, which was to be watched by assistants of the writer. Twenty-four stables were located in this region and were visited weekly by two assistants chosen for the purpose. The result was that on the whole the manure was well looked after and the number of flies in the region in question was very considerably reduced during the time of inspection.

Were simple inspection of stables all that is needed, a force of four inspectors, especially detailed for this work, could cover the District of Columbia, examining once a week all the stables after they had been once located and mapped. The average salary of an inspector is $1,147, so that the total expense for the first year would be about $4,500. But the inspectors' service is complicated by the matter of prosecution. Much of the time of inspectors would be taken in the prosecution of the owners of neglected premises. Moreover, the health officer has found during the summer of 1908 in his prosecution of the owners or managers of insanitary restaurants that his inspectors were practically sworn out of court by the multiplicity of opposing evidence. This means that it will be necessary in such cases to send two inspectors together in all cases, so that the testimony of one may be supported by that of the other. This perhaps would double the number of necessary inspectors, making the expense of the service something over $9,000. It is reasonably safe to state, however, that with such an expense for competent service, or perhaps with a slightly added expense, the typhoid fly could be largely eliminated in the District of Columbia as an element in the transfer of disease; and the difficulty which the authorities have had in locating the cause of a very considerable proportion of the cases of typhoid in the past two or three years indicates plainly to the mind of the writer that the typhoid fly is a much more important element than has been supposed. It is a comforting, although comparatively insignificant, fact that as a matter of common observation in certain sections of the city the typhoid fly has been much less numerous during the past summer than in previous years. The writer is inclined to attribute this to the gradual disappearance of horse stables in such sections, brought about by the rapidly increasing use of motor vehicles.

A significant paragraph in Mr. Newstead's Liverpool report, referred to above, contains the following words:

> The most strenuous efforts should be made to prevent children defecating in the courts and passages; or that the parents should be compelled to remove such matter immediately; and that defecation in stable middens should be strictly forbidden. The danger lies in the overwhelming attraction which such fecal matter has for house flies, which later may afterwards come into direct contact with man or his foodstuffs. They may, as Veeder puts it, "In a very few minutes * * * load themselves with dejections from a typhoid or dysenteric patient, not as yet sick enough to be in hospital or under observation, and carry the poison so taken up into the very midst of the food and water ready for use at the next meal. There is no long, roundabout process involved."

The writer has already referred to this general subject in his remarks on the depositing of excrement in the open within town or city limits, but Newstead's specific reference to children reminds one that in the tenement districts of the older great cities of England and other parts of Europe there occur opportunities for transfer of disease which, while probably less numerous in the newer cities of the United States, nevertheless must still exist and be a constant danger.

We have thus shown that the typhoid or house fly is a general and common carrier of pathogenic bacteria. It may carry typhoid fever, Asiatic cholera, dysentery, cholera morbus, and other intestinal diseases; it may carry the bacilli of tuberculosis and certain eye diseases. It is everywhere present, and may be disposed of with comparative ease. It is the duty of every individual to guard so far as possible against the occurrence of flies upon his premises. It is the duty of every community, through its board of health, to spend money in warfare against this enemy of mankind. This duty is as pronounced as though the community were attacked by bands of ravenous wolves.

As a matter of fact, large sums of money are spent annually in the protection of property in the United States and on matters pertaining to health. But the expenditure for fly protection is very small and misdirected. There is much justification for the criticism published editorally in the Journal of the American Medical Association for August 22, 1908, under the caption "National farm commission and rural sanitation:"

> The President calls attention to the fact that all efforts to aid the farmers have hitherto been directed to improving their material welfare, while the man himself and his family have been neglected. Nowhere is this more marked than in the attitude of the General Government in matters relating to sanitation. It is a trite saying that whereas the Government, through the Department of Agriculture, aids the farmer generously in caring for the health of his hogs, sheep, etc., it does nothing for his own health. The Government issues notices to the farmer of the injury done to his crops by the cotton-boll weevil and the potato bugs and how to combat it, but the injury the mosquito does in spreading malaria to the people who pick the cotton and hoe the potatoes is not impressed on him. The fact that horseflies may carry anthrax to his cattle is dealt with at considerable length, but the diseases which the house fly spreads to the milk and to the farmer's family attract practically no attention. How to build a hog pen or a sanitary barn is the subject of a number of government publications, but how to build a sanitary privy, which will prevent the spread of typhoid, hook-worm, and many other diseases, is regarded as of strictly local interest.

But this criticism is not entirely justified, since there was published by the Bureau of Entomology of the United States Department of

Agriculture in 1900 a Farmers' Bulletin entitled "How Insects Affect Health in Rural Districts," in which all of the points mentioned by the editor of the Journal of the American Medical Association have been touched upon, and at the date of present writing 192,000 copies of this bulletin have been distributed among the people. Moreover, a number of years ago a circular was published on the subject of the house fly, calling attention to its dangers and giving instructions such as are covered in a general way in this article, and some 18,000 copies of this circular have also been distributed. This is an indication that the General Government is by no means blind to the people's needs in such matters as we have under consideration, but further work should be done. That the English Government is awaking to the same need is shown by the fact that in the parliamentary vote of the present year, in aid of scientific investigations concerning disease, one of the projects supported by the General Government was the investigation of Doctors Copeman and Nuttall on flies as carriers of disease.

A leading editorial in the Washington Evening Star of October 20, 1908, bears the heading "Typhoid a national scourge," arguing that it is to-day as great a scourge as tuberculosis. The editorial writer might equally well have used the heading "Typhoid a national reproach," or perhaps even "Typhoid a national crime," since it is an absolutely preventable disease. And as for the typhoid fly, that a creature born in indescribable filth and absolutely swarming with disease germs should practically be invited to multiply unchecked, even in great centers of population, is surely nothing less than criminal.

ENDEMIC DISEASE AS AFFECTING THE PROGRESS OF NATIONS.

In referring to the spread of malaria in Greece, the influence of this disease on the rise and fall of national power has been touched upon in an earlier paragraph of this report. The subject is one of the widest importance and deserves a more extended consideration.

The following paragraphs are quoted from Ronald Ross's address on "Malaria in Greece," delivered before the Oxford Medical Society November 29, 1906:

Now, what must be the effect of this ubiquitous and everlasting incubus of disease on the people of modern Greece? Remember that the malady is essentially one of infancy among the native population. Infecting the child one or two years after birth, it persecutes him until puberty with a long succession of febrile attacks, accompanied by much splenomegaly and anæmia. Imagine the effect it would produce upon our own children here in Britain. It is true that our children suffer from many complaints—scarlatina, measles, whooping cough—but these are of brief duration and transient. But now add to these, in imagination, a malady which lasts for years, and may sometimes attack every child in a village. What would be the effect upon our population, especially our rural population—upon their numbers and upon the health and vigor of the survivors? It must be enormous in Greece. People often seem to think that such a plague strengthens a race by killing off the weaker individuals; but this view rests upon the unproven assumption that it is really the weaker children which can not survive. On the contrary, experience seems to show that it is the stronger blood which suffers most—the fair, northern blood which nature attempts constantly to pour into the southern lands. If this be true, the effect of malaria will be constantly to resist the invigorating influx which nature has provided; and there are many facts in the history of India, Italy, aud Africa which could be brought forward in support of this hypothesis.

We now come face to face with that profoundly interesting subject, the political, economical, and historical significance of this great disease. We know that malaria must have existed in Greece ever since the time of Hippocrates, about 400 B. C. What effect has it had on the life of the country? In prehistoric times Greece was certainly peopled by successive waves of Aryan invaders from the North, probably a fair-haired people, who made it what it became, who conquered Persia and Egypt, and who created the sciences, arts, and philosophies which we are only developing further to-day. That race reached its climax of development at the time of Pericles. Those great and beautiful valleys were thickly peopled by a civilization which in some ways has not since been excelled. Everywhere there were cities, temples, oracles, arts, philosophies, and a population vigorous and well trained in arms. Lake Kopais, now almost deserted, was surrounded by towns whose massive works remain to this day. Suddenly, however, a blight fell over all. Was it due to internecine conflict or to foreign conquest? Scarcely; for history shows that war burns and ravages, but does not annihilate. Thebes was thrice destroyed, but thrice rebuilt. Or was it due to some cause, entering furtively and gradually, sapping away the energies of the race by attacking the rural population, by slaying the new-born infant, by seizing the rising generation, and especially by killing out the fair-haired descendant of the original settlers, leaving behind chiefly the more immunized and darker children of their captives, won by the sword from Asia and Africa? * * *

I can not imagine Lake Kopais, in its present highly malarious condition, to have been thickly peopled by a vigorous race; nor, on looking at those wonderful figured tombstones at Athens, can I imagine that the healthy and powerful people represented upon them could have ever passed through the anæmic and splenomegalous infancy (to coin a word) caused by widespread malaria. Well, I venture only to suggest the hypothesis, and must leave it to scholars for confirmation or rejection. Of one thing I am confident, that causes such as malaria, dysentery, and intestinal entozoa must have modified history to a much greater extent than we conceive. Our historians and economists do not seem even to have considered the matter. It is true that they speak of epidemic diseases, but the endemic diseases are really those of the greatest importance. * * *

The whole life of Greece must suffer from this weight, which crushes its rural energies. Where the children suffer so much, how can the country create that fresh blood which keeps a nation young? But for a hamlet here and there, those famous valleys are deserted. I saw from a spur of Helicon the sun setting upon Parnassus, Apollo sinking, as he was wont to do, toward his own fane at Delphi, and pouring a flood of light over the great Kopaik plain. But it seemed that he was the only inhabitant of it. There was nothing there. "Who," said a rich Greek to me, "would think of going to live in such a place as that?" I doubt much whether it is the Turk who has done all this. I think it is very largely the malaria.

In considering carefully this suggestive argument of Major Ross, does it not appear to indicate the tremendous influence that the prevalence of endemic disease must exert upon the progress of modern nations, and does it not bring the thought that those nations that are most advanced in sanitary science and preventive medicine will, other things being equal, assume the lead in the world's work? Who can estimate the influence of the sanitary laws of the Hebrew scriptures upon the extraordinary persistence of that race through centuries of European oppression, centuries full of plague years and of terrible mortality from preventable disease? And what more striking example can be advanced of the effect of an enlightened and scientifically careful attention to the most recent advances of preventive medicine upon the progress of nations than the mortality statistics of the Japanese armies in the recent Russian-Japanese war as compared with the corresponding statistics for the British army during the Boer war immediately preceding, or the American army during the Spanish war at a somewhat earlier date?

The consideration of these elements of national progress has been neglected by historians, but they are nevertheless of deep-reaching importance and must attract the immediate attention in this age of advanced civilization. The world has entered the historical age when national greatness and national decay will be based on physical rather than moral conditions, and it is vitally incumbent upon nations to use every possible effort and every possible means to check physical deterioration.

SUMMARY OF LOSSES FROM INJURIOUS INSECTS.

This report on the economic loss to the people of the United States through insects that carry disease is one of a series of reports made to the Commission on the Conservation of Natural Resources on the losses due to injurious insects. The insect losses in the United States are undoubtedly heavier than in any other country in the world. There are many insect pests for every plant grown on the farm and for every kind of tree represented in our natural forests. All domestic animals suffer seriously from parasitic and other insects, and above the reduction in the annual increase of products is the heavy loss occasioned by insects to the accumulated stores of previous years of such staples as grains, tobacco, manufactured woods, hides and furs, and certain animal food products. There is in addition, also, the serious check on production caused by the prevalence of insect-borne diseases.

Estimating all of these losses at the lowest reasonable percentage, a total so enormous is reached that it staggers the belief of anyone who has not given the subject careful study or considered the enormous annual output of products involved.

To meet the requirements of the schedule of inquiries submitted, the losses which are chargeable to insect pests fall under four heads, namely, (1) relating directly to plant products other than natural forests; (2) relating to natural forests and forest products; (3) due to insect enemies of live stock; and (4) due to the relation of insects to disease. To get a comprehensive view, the amount of loss estimated as falling under each of these four heads is here indicated.

Subject.	Percentage of loss on annual output or value.	Amount of loss.
Plant products of the farm	10-30	$652,500,000
Natural forest products	10	130,000,000
Animal products	10	267,000,000
Insects versus disease		200,000,000
Total		1,249,500,000

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